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THE FRANKLIN INSTITUTE

Stated Meeting, held Wednesday, April 19, 1905.

The Improvement of the Delaware River and Harbor and the Landing Facilities of the Port of Philadelphia.

BY GEORGE S. WEBSTER, Member of the Institute.

Chief Engineer Bureau of Surveys, Dept. of Public Works, Philadelphia.

[A description of the work done by the City of Philadelphia, in conjunction with the United States Government in the improvement of the channels of the Delaware and Schuylkill Rivers, and the improvement of the landing facilities of the port, by the widening of Delaware Avenue and the construction of larger and more commodious piers.—THE EDITOR.]

This subject may best be considered under two headings: (1) The Improvement of the River Channel, which was begun by the United States Government, and supplemented by appropriation for the State of Pennsylvania and the City of Philadelphia; and (2) the Landing Facilities of the Port, which are being carried out by the City and the owners of the wharf property.

HARBOR IMPROVEMENTS.

The project as approved by the United States Board of En-

gineers for improving what is known as the Harbor of Philadelphia, which extends in front of the city from Fisher's Point to Kaighn's Point, a distance of five and a-half miles, involved the removal of Smith's and Windmill Islands, covering about twenty-five acres, a portion of Petty Island of forty acres, and the formation of a dredged channel of a width of 1900 feet between pierhead lines, of a least depth of 26 feet at mean low water for 1000 feet in width along the Philadelphia front, and for the remaining 900 feet of width, of a depth decreasing from 26 feet to 12 feet at low water along the Camden side.

On August 11, 1888, Congress appropriated $500,000.00 to inaugurate the work. The Act provided that the title to Smith and Windmill Islands and that portion of Petty Island taken be first acquired by the United States, but limited the amount to be expended for that purpose to $300,000.00. The State of Pennsylvania, by Act of May 31st, 1889, appropriated $200,000.00 and the City of Philadelphia, by ordinance of May 15th, the same year, appropriated $230,000.00 to aid in securing the title to the Government, and the City actually paid of this sum, $208,652.86. The harbor work was begun in 1891, but very little was accomplished until 1893, the work in the harbor under the project being completed in 1897.

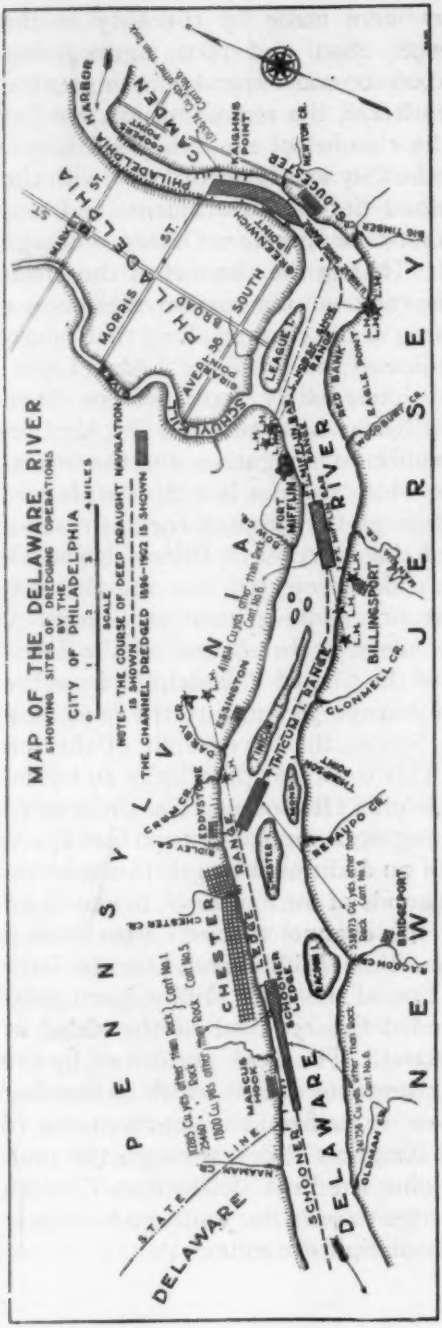
DELAWARE RIVER IMPROVEMENT.

The project under which the work of improving the Delaware River from the harbor to the sea was being carried on was adopted by the United States Government early in 1885, and provided for the formation of a channel 600 feet wide and 26 feet deep at mean low water.

Owing to the inadequacy of the Government appropriation and in response to the demands of commerce, together with the urgency for obtaining at once a channel 600 feet wide, and 26 feet deep, from the City to deep water in the Bay, to better enable the City of Philadelphia to compete with the other large shipping ports on the Atlantic Coast, Councils, on December 28th, 1894, appropriated $225,000.00 to supplement the work of the United States Government in the removal of shoal places and other impediments, interfering with the navigation of large vessels to and from the Port of Philadelphia.

Additional appropriations were made by the City in the years 1895, 1896, 1897, 1898, 1899, and 1902, aggregating $1,555,000.00, of which $770,000.00 was expended in improving the channel of the Delaware River, the remaining amount being applied to deepening the channel of the Schuylkill River.

The work undertaken by the City was in accordance with the adopted project of the United States Government, and was under the general supervision of the Engineer Officer in charge of the River Improvement. That in the channel of the Delaware River comprised (1) the removal of a portion of Schooner Ledge Rock and the deepening of the channel along that range. The ledge is situated in the line of the Schooner Ledge Lighthouse range, opposite and immediately south of the Steel Works Wharf at South Chester. It resulted in the removal of a dangerous obstruction to navigation, and the formation of a channel 600 feet in width and not less than 26 feet in depth at mean low water, through the ledge of rock at that locality. Also the removal of that portion of Illinois Rock adjacent to Schooner Ledge, which projected into the channel; (2) The removal of the bar or middle ground at Greenwich Point and the deepening of the western channel of the Delaware River along the front of the City of Philadelphia from the prolongation of the lines of Avenue 38 south to the prolongation of the lines of Morris Street, the lower limit of the improvement of the harbor. This work was practically an extension southward of the Philadelphia Harbor, and was prosecuted within channel boundaries ranging from 950 to 1050 feet apart, resulting in the formation of an additional length to the channel, and to the anchorage grounds of the harbor of 10,000 lineal feet; (3) the deepening of the channel through Fort Mifflin Bar, about midway between Fort Mifflin and Lincoln Park Wharf, immediately in the line of the Fort Mifflin Bar Lighthouse range. It also included the removal of the shoal at the south end of Tinicum Island. The work performed by the City resulted in securing a channel of a least width of 600 feet and 26 feet deep at mean low water from the southern end of the Philadelphia Harbor at Kaighn's Point, through the middle grounds of Greenwich Point, the Fort Mifflin Bar, Tinicum Island shoal and Schooner ledge to near the southern boundary of the State, a distance of about eighteen miles.



On September 20th. 1899, in accordance with a report of the Board of Engineers, the Secretary of War approved the present project for improving the Delaware River, by creating a channel 600 feet wide and 30 feet deep from Christian Street to deep water in the Delaware Bay.

In this report no dikes were recommended for the maintenance of the channel, but the formation of an island to be made of the material excavated was authorized opposite Reedy Island.

The Government has been at work on this project ever since its approval, and work has advanced from the Delaware Bay northward as rapidly as the available funds would warrant, the portion from the Bay to Fort Delaware, a distance of twenty-one miles, being completed.

Owing to the increase in the size and draught of modern ocean steamers a demand has arisen in the Commercial, Maritime and Trade Organizations of this city for the adoption of a project for a channel 35 feet deep at mean low water, and at

the last Congress a resolution was passed by the Senate directing the Secretary of War to report to the Senate, as early as practicable, an estimate of the cost of deepening the channel of the Delaware River, Pennsylvania, from Allegheny Avenue, Philadelphia, to deep water in Delaware Bay, to 35 feet.

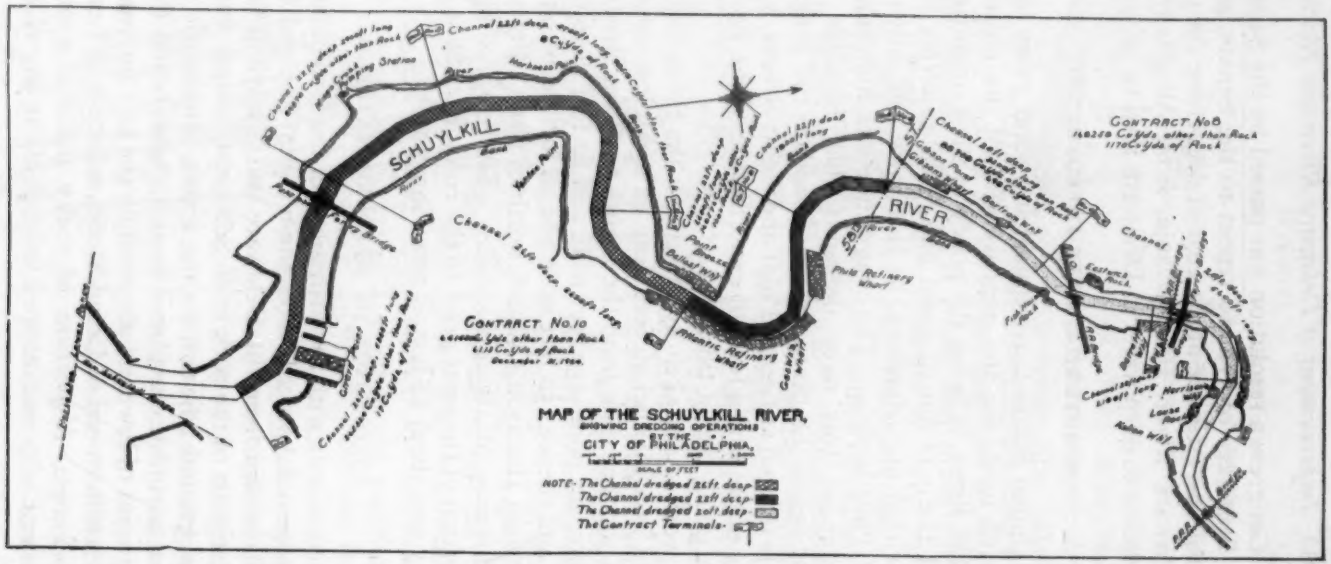
SCHUYLKILL RIVER IMPROVEMENT.

The United States Government in recent years has not appropriated funds for the improvement of the channel of the Schuylkill River, it being the policy of the Committee on Rivers and Harbors not to grant any funds to rivers located entirely within municipalities, so this work has fallen upon the City of Philadelphia. The magnitude and importance of the commerce of this river demands that facilities for deep-draught vessels be given, to accommodate the great shipping interests located at Girard Point and Point Breeze, a large percentage of the whole foreign export trade of the Port of Philadelphia going out of this river.

The work undertaken by the city in the Schuylkill River has resulted in a channel 26 feet deep at mean low water and 250 feet to 300 feet wide from the mouth to Point Breeze Harbor, and from this point 250 feet wide and 22 feet deep to Gibson's Point, and thence 150 feet wide and 20 feet deep to a point 500 feet beyond Harrison's Wharf, north of Gray's Ferry Bridge, a total distance of about six miles. The controlling depth in this portion of the river prior to the commencement of work by the city was about 18 feet at mean low water.

DISPOSITION OF DREDGED MATERIAL.

In accordance with the provisions of the Ordinance of Councils, approved April 2d, 1898, the material dredged by the City of Philadelphia from the Delaware and Schuylkill Rivers, with the exception of the rock from Schooner Ledge, was deposited on low ground adjacent to the rivers, within the city limits. A great part of it was placed upon League Island Park, a tract of 300 acres of low land acquired by the city for park purposes at the southern end of Broad Street, adjacent to League Island Navy Yards. A portion of rocky material removed from Schooner Ledge was dumped in front of the city as a support to


SCHUYLKILL
RIVER
CONTRACT No.8
CONTRACT No.10
MAP OF THE SCHUYLKILL RIVER,
SHOWING DREDGING OPERATIONS
BY THE
CITY OF PHILADELPHIA.
NOTE- The Channel dredged 25ft deep
The Channel dredged 22ft deep
The Channel dredged 20ft deep
The Contract Terminals

the piles of the bulkheads and new piers constructed along Delaware Avenue. The remaining rock was deposited back of Chester Island in such a location as not to interfere with navigation.

RECENT LEGISLATION.

The Pennsylvania State Legislature recently passed an appropriation of $375,000.00 to expedite the work of improving the channel of the Delaware River between the City and the Bay, conditioned upon the City of Philadelphia making a like appropriation. This bill is now in the hands of the Governor for his approval, the work to be done by the Bureau of Surveys, Department of Public Works, of this city, and in accordance with the adopted project of the United States Government.

LEADING FACILITIES OF THE PORT.

As the work of increasing the depth of the channel of the river was progressing, preparations were made for increasing the landing facilities of the port. The necessity of wharves of sufficient length to dock large vessels was recognized and a revised wharf line increasing the limit to which piers may be extended in the Delaware River was established by ordinance approved October 7th, 1891.

In accordance with the ordinance and the project of the United States Engineers for the improvement of the harbor of Philadelphia the bulkheads and wharf lines were so established as to admit of the widening of Delaware Avenue and the extension of the piers along the river front so as to obtain lengths from 500 feet to 650 feet.

HISTORY OF DELAWARE AVENUE.

Upon the original plan or map of the City of Philadelphia, made by Thomas Holme, in 1682, the present Front Street corresponded with the west bank of the Delaware River. Lots were sold fronting on the westerly side of Front Street, the easterly side remaining as a bank or open common.

Between the years 1684 and 1690 the demands of commerce and the occupancy of certain portions of the river bank by stores caused a change in policy, as patents for bank lots lying

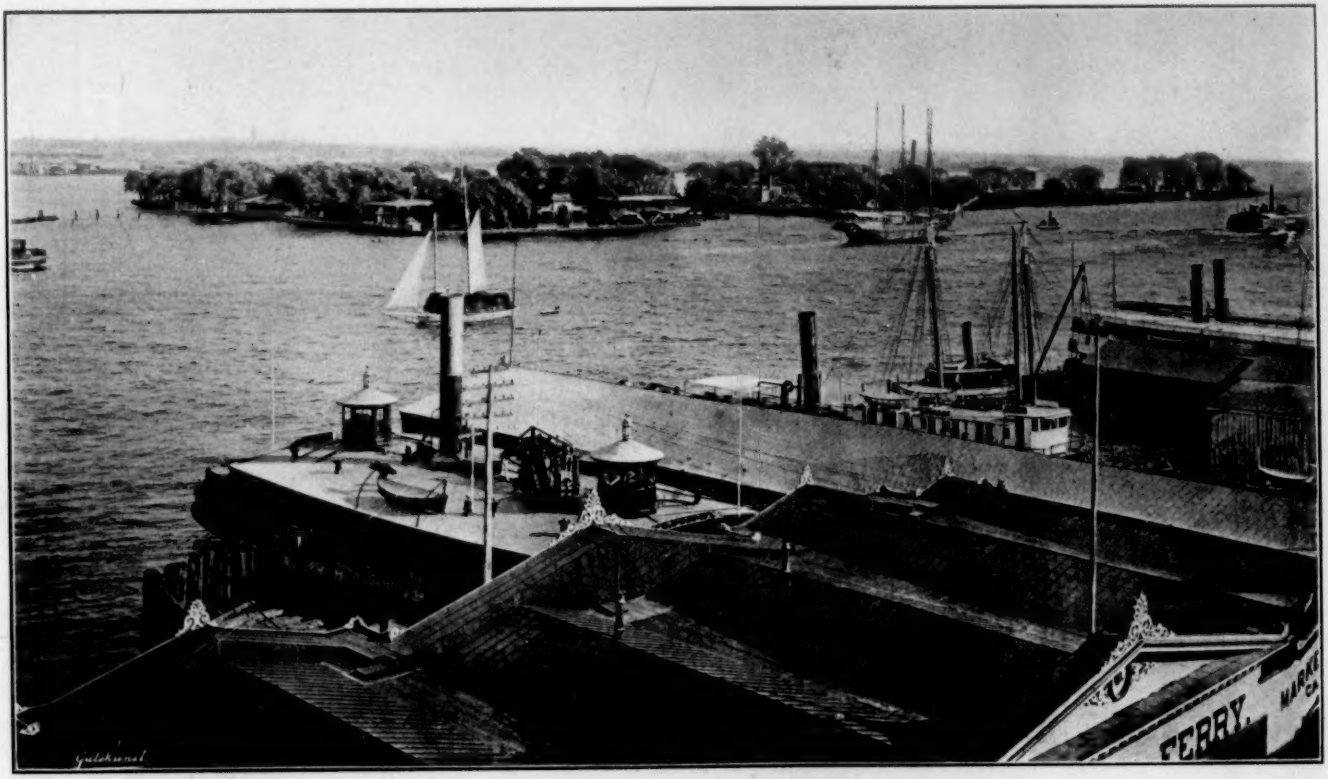
eastward of Front Street were issued to citizens prior to and during 1690-1691.

These patents restricted the heights of buildings on the bank side of Front Street, which gave rise to a petition from the owners to build as "high as they pleased." After consideration the Commissioners of the Proprietary formulated what is known as the "Regulation of the Bank." The petition was granted, one of the conditions being that all owners "shall regularly leave thirty foot of ground in the clear, for a cartway and along the said whole bank, and in convenient time shall make the same to be a common and public cartway for all persons, by day and by night, forever hereafter." This indicates the way in which Water Street was first laid out.

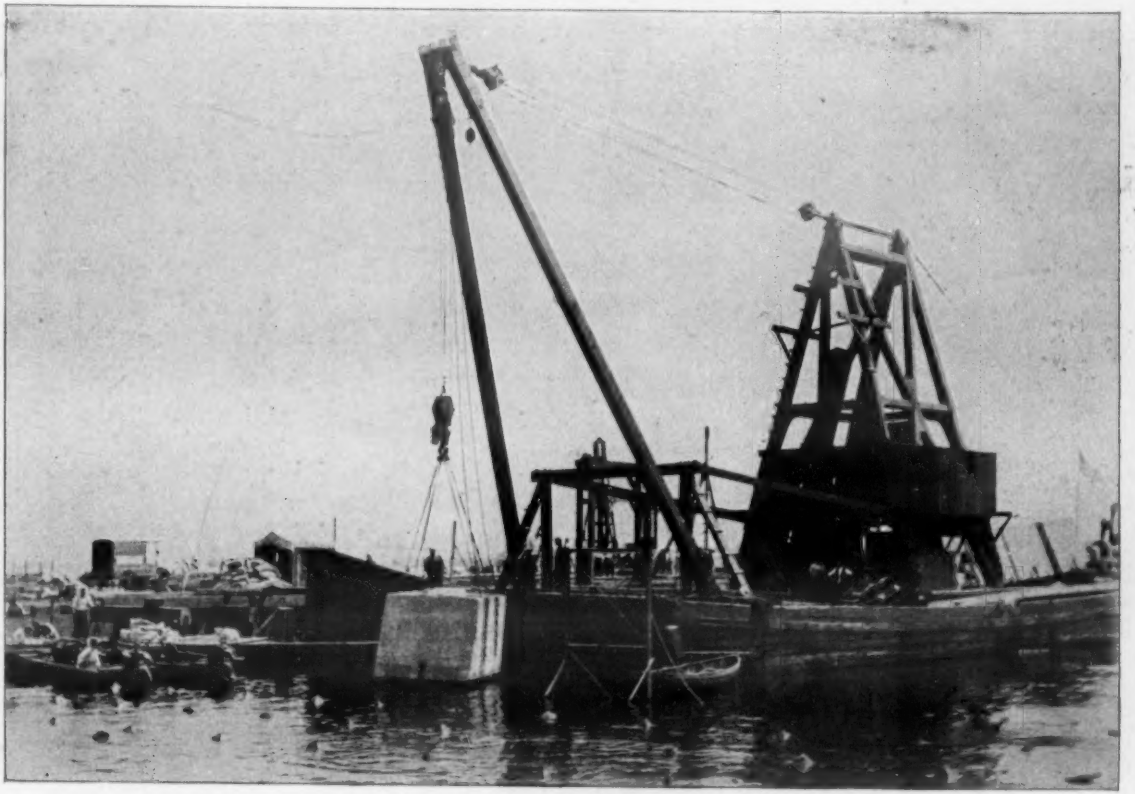
Commerce during the time of Stephen Girard had so increased, and with it the extension of wharves further into the river and the building of stores near the wharves, as to demand further encroachments upon the river. A firm belief in the future commercial importance of Philadelphia and a keen grasp of the necessities of the time and of the future, undoubtedly were possessed by Stephen Girard, to enable him to plan as he did, not only for laying out a new front street (Delaware Avenue) on the Delaware River, but to plan and provide for its expansion, as indicated by the following section of his will, proved December 31st, 1831, in which he set aside $500,000.00, the interest to be used as follows:

"To lay out, regulate, curb, light, and pave a passage or street on the east part of the City of Philadelphia, fronting the River Delaware, not less than twenty-one feet wide, and to be called Delaware Avenue, extending from Vine to Cedar Streets, all along the east part of Water Street squares, and the west side of the logs which form the heads of the docks, or thereabouts; and to this intent to obtain such Acts of Assembly, and to make such purchases or agreements, as will enable the Mayor, Aldermen, and Citizens of Philadelphia to remove or pull down all the buildings, fences, and obstructions which may be in the way, and to prohibit all buildings, fences or erections of any kind to the eastward of said Avenue; to fill up the heads of such of the docks as may not afford sufficient room for the said street; to compel the owners of wharves to keep them clean and covered completely with gravel or other hard

Jour. Franklin Inst. Vol. CLX., Sept. 1905.



Smith and Windmill Islands, now removed.



Setting foundation blocks for bulkhead.

materials, and to be so leveled that water will not remain thereon after a shower of rain; to completely clean and keep clean all the docks within the limit of the City fronting on the Delaware; and to pull down all platforms carried out from the east part of the City over the River Delaware, on piles or pillars."

By Act of Assembly of March 24th, 1832, the Mayor, Aldermen and Citizens of Philadelphia were authorized to carry into effect certain improvements and execute the trusts under the will of Stephen Girard.

Delaware Avenue was first laid out twenty-five feet wide from Vine to Cedar (South) Streets under authority of an Ordinance of Councils, approved February 27th, 1834, and by various ordinances covering a period from 1834 to 1839, the opening of portions of this Avenue were authorized. Proceeding under authority of the Act above quoted, the Trustees under the will of Stephen Girard performed and bore the expense of this work, covering a period from 1834 to 1845.

The growth of commerce at this time demanded further increase in the facilities, and the Trustees, acting under the same authority, between the years 1857 and 1867, widened the Avenue from twenty-five to fifty feet between Vine and South Streets.

That portion of the Avenue between Dock Street and Washington Avenue was placed upon the City Plan of the width of eighty feet by Act of Assembly of May 15th, 1871, and Ordinance of Councils of May 13th, 1872.

Upon the establishment of the new bulkhead line admitting of the recent widening of Delaware Avenue, Councils by ordinance of June 23d, 1893, authorized the placing of the Avenue upon the City Plan between Christian Street and Laurel Street to a least width of 150 feet, the easternmost line to conform to the bulkhead line established by the Secretary of War. Plans were prepared in accordance with the ordinance, the increased width of the street being taken from the docks on the easterly side of the Avenue, except at Pine and Lombard Streets, where corners of buildings on the westerly side were cut off, and between Market and Walnut Streets, where the westerly line of the Avenue as laid down cuts off several feet from the

Concrete bulkhead.

fronts of properties. This plan was confirmed by the Board of Surveyors November 19th, 1894.

By Ordinance of March 11th, 1895, Councils authorized the physical widening of the Avenue between Vine and South Streets, except the properties on the west side between Market and Walnut Streets, and empowered the Mayor of the City to negotiate with the property owners with a view of adjustment of the damages by reason of the taking of the property for the widening.

These negotiations resulted in a majority of the owners agreeing amicably with the city upon the amount of damages suffered, which were finally adjusted without litigation, with the exception of four owners on the east side of the Avenue, and a few owners on the westerly side, whose interests were such that the basis upon which negotiations were made could not be accepted, but for which adjustments were finally made on a different basis.

As a result with the settlements with these latter owners the City acquired 363 feet 5¾ inches of additional water front property, and coincident with other corporations and individuals at once proceeded to tear down old buildings and build new and enlarged structures, some of them of steel, giving additional accommodations to shippers and inviting commerce to the port.

The City of Philadelphia owns valuable water-front property, between Vine and South Streets, including piers at the foot of Race, Arch, Chestnut and Dock Streets, also north of Race Street, and other property at the foot of Vine Street, Market and South Streets, being used by ferry companies under leases.

AUTHORIZATION OF WORK.

On January 13th, 1896, a loan was created of $1,500,000.00 for the purpose of carrying on the improvement of Delaware Avenue, and the work of widening, constructing bulkheads, building of sewers, and extension of the City piers was authorized by Ordinance of March 31st, 1896.

By Ordinance of November 27th, 1896, the Board of Directors of City Trusts was authorized to join with the City of Philadelphia in carrying on this work, and agreed to set aside the sum of $650,000.00 for this purpose, which represented the sur-

Delaware Avenue after Completion of Improvement.

plus interest which had accumulated from the original bequest of $500,000.00 by Stephen Girard.

The necessary legislation having been enacted measures were taken to begin the construction of the work. The first essential was the building of a bulkhead about 5200 feet in length and the reconstruction of about 8000 lineal feet of sewers of various sizes in the streets adjacent, on a system by which the ordinary flow of the sewage was intercepted and carried out to discharge at the pierhead line, while the storm water was permitted to discharge at the heads of the docks. The work also included the filling-in of the reclaimed areas and the paving of the entire Avenue.

BULKHEAD WALL.

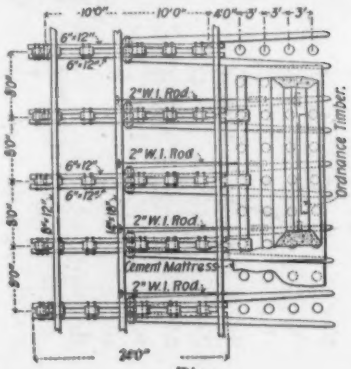
The reclaiming of a strip of from 70 to 100 feet in width, taken from the docks, having a depth of water varying from four to twenty feet, covering a layer of soft mud from ten to forty feet thick, resting on the gravel bed of the river presented a number of problems for solution: (1) The best method of dealing with this soft river bottom to insure stability in the completed structure; (2) the best way to confine the filling to prevent movement in the bulkhead; and (3) the best type of bulkhead to adopt to meet the requirements of stability, economy and appearance.

The plan adopted was for a concrete wall resting on piles sawed off twelve feet below mean low water, excepting short sections back of the piers and ferries, which consisted of a concrete wall upon timber platform.

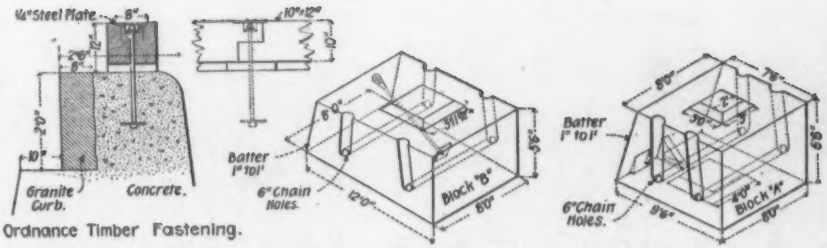
The consistency of the mud filling in the docks was such that it was essential to dredge it out and deposit coarse gravel or broken rock as a support for the piles, which were then driven and sawed off about twelve feet below mean low tide.

Upon these piles a foundation for the concrete wall, consisting of two courses of large concrete blocks, weighing thirty-two tons each, were placed, the upper block being visible at low water. Upon these blocks forms were erected and the balance of the concrete wall built in place.

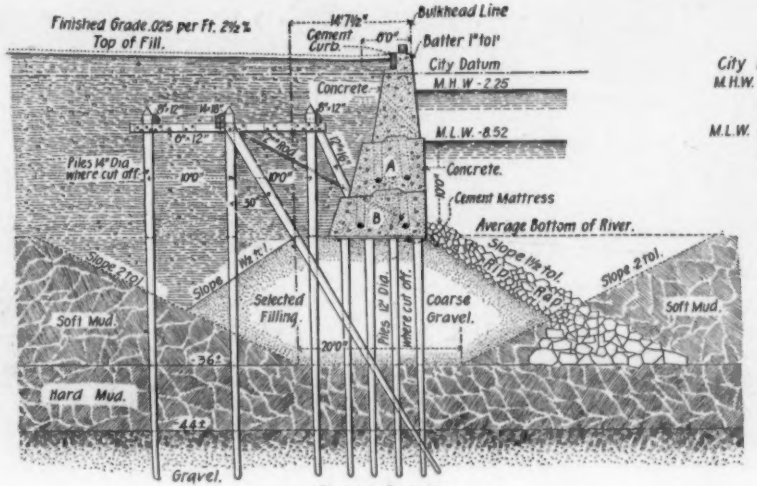
The system adopted for intercepting the sewage did away with a nuisance which was for a long time the source of com-



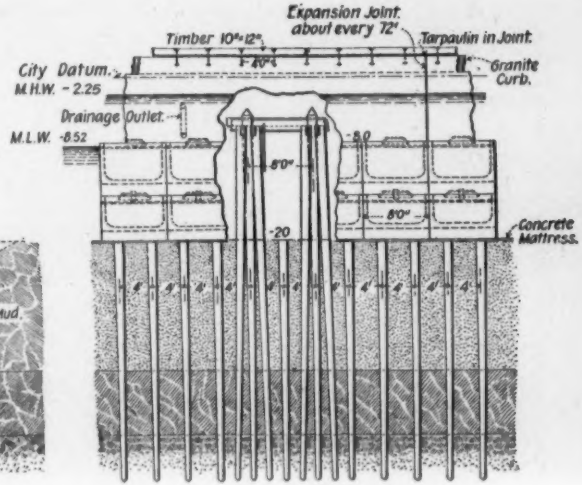
Plan.



Ordnance Timber Fastening.



Cross-Section.



Front Elevation.

THE ENGINEERING RECORD.

Design of concrete bulkhead.

plaint from the pier owners and from the traveling public using the ferries.

CONSTRUCTION OF PIERS.

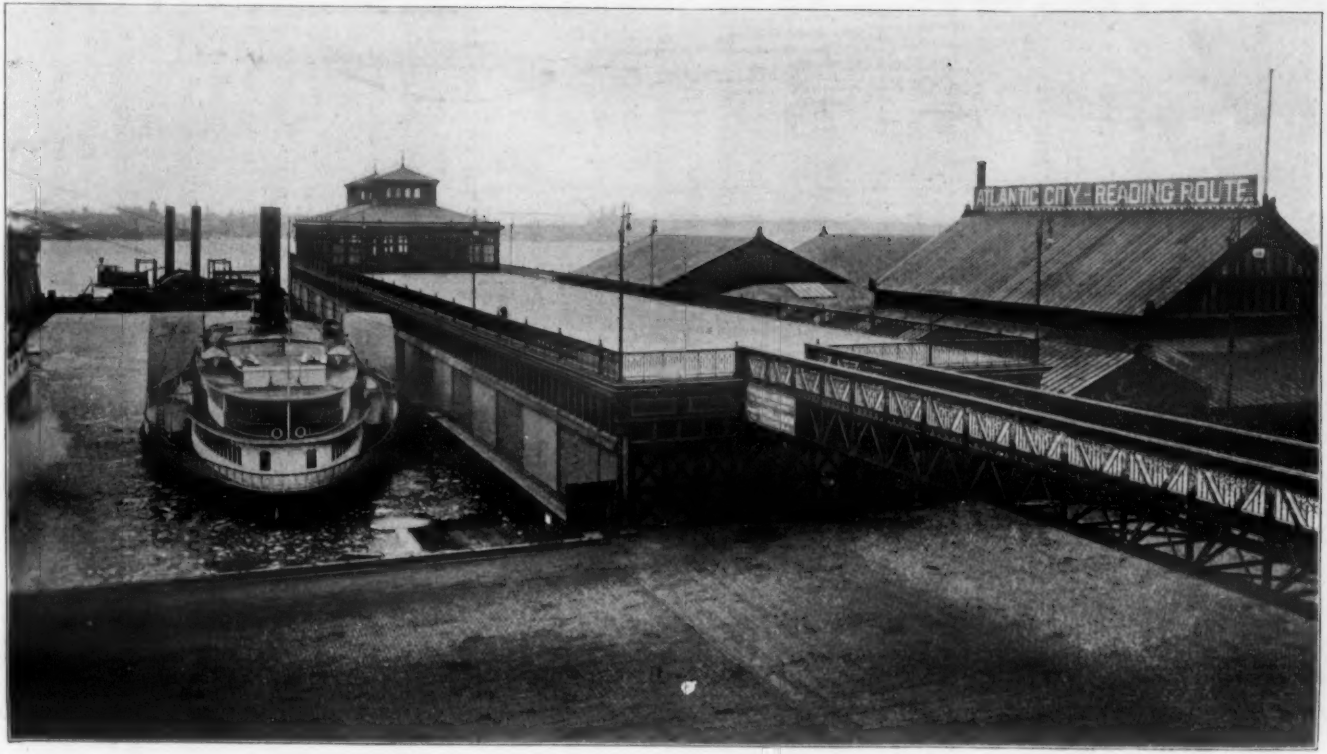
In connection with the work of widening Delaware Avenue the city reconstructed and extended the piers upon its own property at Race, Arch and Chestnut Streets, the general dimensions of the three being 80 feet in width, by lengths varying from 530 to 540 feet.

The City also leased property north of Race Street to the Baltimore & Ohio Railroad Company on an improvement lease, under the condition it should construct a pier 60 feet by 540 feet and turn the same over to the City in good condition at the termination of its ten years' lease.

The substructures of the piers constructed by the City and most of those by individuals were open pile foundations. In order to provide a footing for the piles, coarse gravel or broken stone was dumped on the site of the piers to a height of thirty feet below low water, and the piles afterwards driven.

The piers at Chestnut Street and Race Street were considered suitable places for providing pavilions for the accommodation of the public, to be used for recreation purposes. To this end more elaborate structures were designed at these locations, comprising, in addition to the freight facilities on the lower decks, upper decks and covered pavilions.

The results obtained from the improvement of the channel of the Delaware River and the landing facilities of the port, to those who will recall the dilapidated condition of the sheds and stumps of piers, which existed prior to the commencement of the work, are fully apparent. From a narrow avenue fifty feet in width, with numerous ruts in the paving, upon which, during the hours of business, there were several lines of drays badly blocked at times, and forming a barrier to pedestrians to and from the ferries and piers, there is now a broad avenue, permitting of the speedy removal and delivery of freight. Piers have been constructed and freight stations have been greatly enlarged and new and commodious buildings of a permanent character upon the east line of the Avenue have been built. The rapidity of the growth of these improvements has exceeded all expectations.



Recreation pier at Chestnut Street.

Negotiations have been completed with the owners of property between Vine and Green Streets with a view of carrying the improvement to the northward. This work now awaits authorization from Councils.

The completion of the paving upon a concrete base had been delayed for several years, until by agreement the three steam railroads having rights upon the Avenue acceded to the demands of the city officials, fixing upon three tracks as the maximum number to be allowed.

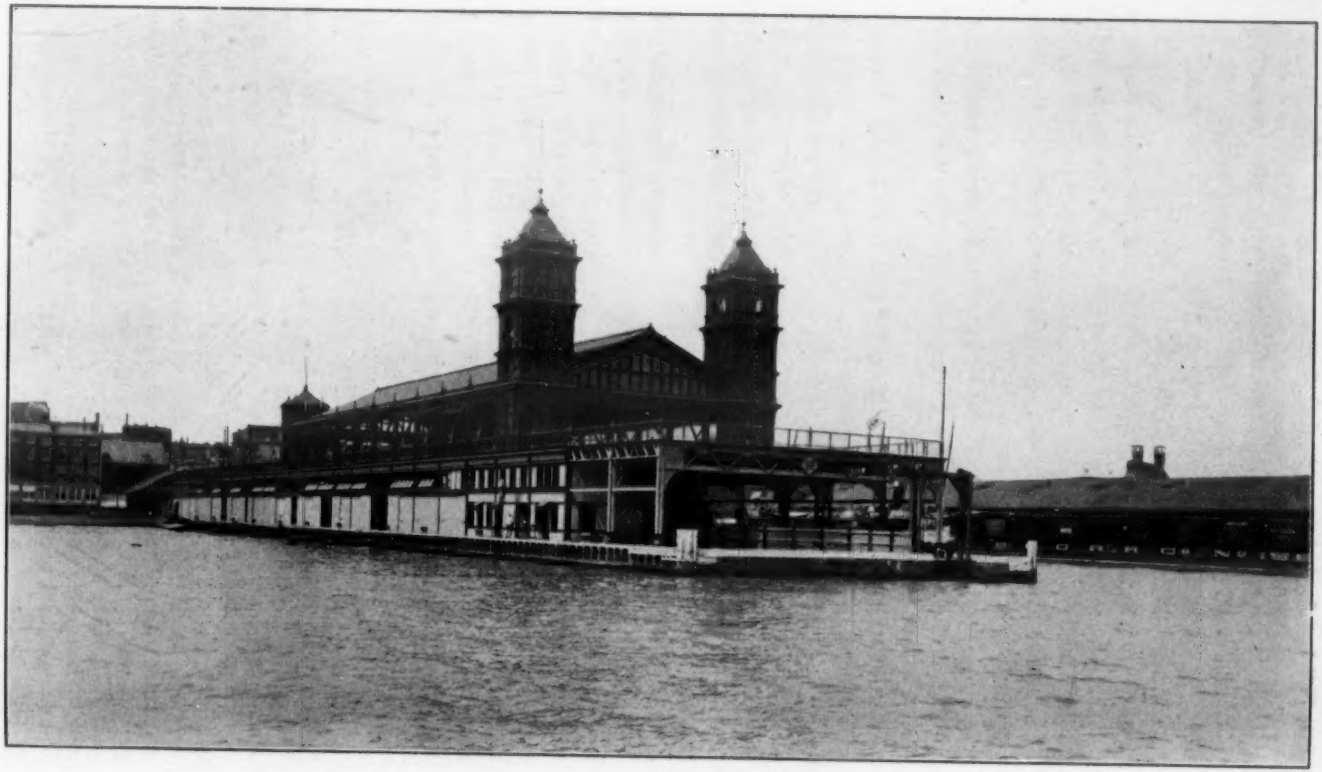
Thereafter the Girard Estate placed the paving under contract, setting aside additional funds for the purpose, and completed it late in the year 1904.

The total expenditure by the City and the Girard Estate in widening Delaware Avenue and constructing the piers and otherwise improving the facilities of the port was $2,247,361.05, of which amount the Girard Estate expended $779,933.03 and the City $1,467,428.02. $999,856.70 of the City's expenditure was for acquiring the additional property and for paying damages for the widening of the avenue.

The Philadelphia Rapid Transit Company, lessee of the Frankford Elevated Passenger Railway Company, is authorized ,by ordinance, to construct an elevated railroad on Delaware Avenue, between Vine and South Streets, and plans are now being prepared for the portion south of Arch Street, with a connection to the Market Street Subway. This will greatly facilitate passenger travel, as convenient connections will be made with all the ferries, steamship and steamboat lines.

STEAM-TURBINE OPERATION.

According to *Power*, July, 1905, in two instances lately reported turbines having a multiplicity of blades have lost a large quota of them without coming very seriously to grief. In one case the turbine in a cotton mill was opened every night and as many of the blades put back as possible, the case put back and the machine put to work next day as though nothing were wanting. In another plant, it was noticed that it was necessary to cut more resistance than ordinary out of the field coils to keep up the voltage and the turbine was found to be running slow. Investigation showed that all, or nearly all, of the blades of the intermediate stage were in the bottom of the case. The turbine ran along in this condition until an opportunity afforded to put them back and without an appreciable difference in the cost of aperation.



Recreation pier at Race Street.

Electrically Welded Screw Caps and Bolts.

[*Being the Report of the Committee on Science and the Arts on the Method of the Cleveland Cap Screw Co. Sub-Committee, J. Logan Fitts, Chairman; D. Eppelsheimer, Jr., Arthur Falkenau, Chas. E. Ronaldson.*]

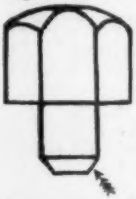
"Cleveland Cap Screw Co.'s Cap Screws and Bolts."

[No. 2312.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the "Cap Screws and Bolts," made by the Cleveland Cap Screw Co., of Cleveland, Ohio, reports as follows:

The cap screws made by the company named are intended to be used for the same purposes and in the same manner as cap screws have heretofore been used. The novelty of these screws is the method of their manufacture, in which the welding together of the head and body of the screw is done electrically, die-drawn stock being the material used, prepared for the purpose, and the heads are made to conform to the U. S. Standard, or Franklin Institute head. The following description is quoted from a letter from the manufacturers.

"For the heads we use specially die-drawn stock, hexagon, square or round, according to style of head required. This



stock is drawn very accurately, with a variation not exceeding .003. The heads are cut from the bar on automatic machines, which turn a projection or shoulder to the diameter of the screw to be welded, as shown in the accompanying sketch.

The heads and stems are placed in the moulding machine and held firmly by copper vises, which are clamped to gun metal platens of large section, and to which are connected the terminals of the secondary circuit of the welder, which are moved on steel ways by hydraulic pressure. The sections to be welded are then brought together, thus completing the secondary circuit; the primary circuit being completed through a break-

switch, operated by a foot lever. The current is allowed to pass through these sections until they are brought up to a welding heat, then released at the same time the pressure is applied, forcing the two together, expelling any possible slag, or deteriorated metal, and forcing up a burr.

"The next process is the milling down of the burr, which is done by machinery especially constructed for this purpose. At the same time, the top of the head is shaved and trimmed, the under part of the head is forced and the end pointed. It will be seen that by this process we get absolute uniformity in the length of the screw, height of the head, and in the alignment of the head and body.

"The blank is then ready for threading. Here again we have special machinery, in which we employ lead screws for the purpose of taking all strains off the dies except those incident to removing the necessary material in forming the threads, which guarantees accurate threads.

As we cut the threads on the surface of the die-drawn stock and not the center, we have found by actual tests made for us that they have a much greater tensile strength than the milled or upset screws. With the milled screw, the thread is cut on the core of the material, which is conceded to be much weaker than the surface material, and with the forged-head screw an inferior grade of material is used. The fact that we use a special quality of stock enables us to give our screws a very fine finish."

Quoting again another letter: "We call attention to our new process, case-hardened or Harveyized head cap screws, with soft die-drawn steel body, thereby avoiding all danger of threads being chipped or broken off.

"Also to our electric-welded brass head to steel body cap screw, which we are making in large quantities for switch-board and other electrical machinery manufacturers.

"We manufacture screws in all diameters up to and including 2″ diameter by any length."

The following is quoted from a report made by Mr. Eppelsheimer, who visited the works:

"This transformer is built into the base of the machine, forming a part of it, and has supplied to it an alternating current of 300 volts, with current necessary, which, for ¾″ bolts, is

about 97 amperes; and this is reduced to 2 volts and corresponding amperes, *i, e.*, about 14,500.

"As the two abutting surfaces are brought to the necessary heat the current is thrown on and off, by a foot treadle operating the primary circuit, allowing the heat to become uniform over the section, and then when the proper heat is obtained the whole is forced together with a horizontal movement of the jaws holding the head, with a pressure of from two and a-half to six tons, in some cases by hand-power through the medium of gears or by direct hydraulic pressure.

"The placing of brass heads on steel-bodied bolts or any other combination of metals is quite as easily accomplished, only on account of the difference in electrical conductivity the heads are made thus (arrow shows where the weld is to be, metal is champfered off or cut away) and this probably accounts for the serrated appearance of shavings taken from the weld of such bolts."

The Committee has examined the samples sent, and has had a few special pieces made for test. The welding of heads to bolt bodies is not new, but cap screws made with electrically-welded heads, within the knowledge of the Committee, is new.

The pieces mentioned as made from test were tested on an Olsen machine by pulling the heads off, resulting as the average of the five pieces, as follows:

The pieces were $\frac{3}{4}''$ screw bodies, with U.S.S. Hex, heads, bodies 8″ long—no threads. Average diameter .7485″—elastic limit 29920 pds. Ultimate strength 37900 pds. Elongation in 2″, .23″ (varying from .1 to .36″). Elastic limit per sq. in. 69000 pds., and about 86000 pds. ultimate strength per sq. in. The full table is appended. Eighty per cent. of the pieces gave way at the weld, with granular fractures; piece No. 3 giving way below the weld, in the body of the bolt, showing a true fracture of silky character. The welding appears to effect an annealing of the metal, as the elongation occurred within a small space at and near the weld on each piece.

Several samples of $\frac{3}{4}''$ body and about 6″ long, with a head welded on each end, were tested for torsion at the laboratory of the University of Pennsylvania by Prof. Spangler and your chairman, and the conclusion reached was, that at the welds, or near them, was the weakest point (not considering the

bottom of threads of finished bolts) but that these points compare favorably with the tensile tests showing 80,000 lbs. per sq. in., average angle about 90°.

The Cleveland Cap Screw Co. have furnished us with a copy of a report of tests made by the Wellman, Seaver, Morgan Co., and as we understand these tests were made with threaded bolts and none gave way at the welds, in this report a much higher tensile strength as the average of all sizes of screws is given, viz.: 97862 pds. per sq. in.

In order to determine the structure of the welds, an all-steel bolt was cut longitudinally through the head and body to a point below the weld, then carefully polished and etched with acid solution. The surface showed a fibrous arrangement of the particles of the metal, and at the weld a line of about $\frac{1}{16}$" wide of quite a different character with no fibre markings, but each side of this the lines of the fibre curved outward as would naturally occur in forcing them together when hot. Test piece No. 5, after pulling head off, treated the same manner, and showed positive evidence of having broken at the weld.

A piece with brass head welded on was similarly treated showing the same fibre in the steel, but nothing marked in the brass. It was specially noted that a narrow line of copper color showed next to steel and that at the point of contact of brass and steel, the steel was eaten to a greater depth by the acid. From this it would appear that an electric couple is formed and a noticeably more rapid action occurred on the application of the acid.

The Committee find that here is a derth of information in the matter of physical tests of electrically-welded joints.

From "Electric Engineering Formula," page 673, Sir Frederick Bramwell found that $1\frac{1}{8}$" round iron bars 14" long could be welded by the "Electric" process at the rate of $2\frac{1}{4}$ minutes per weld, giving a strength of 48000 pds. or 91.9% of the original bar, while by the ordinary blacksmith's method, 4 minutes were required per weld giving 89.8% of strength. In the former cases unskilled labor was used, while in the latter there were experienced smiths employd.

To show the adaptability of the electrically welding a number of metals, we quote further: "Prof. E. Thomson has a bar $\frac{3}{8}$" diameter made by this process of nine different metals."

It is well understood that in screws milled from solid stock, the threads are cut on a body which is softer and weaker than the original outer surface and while a great economy in metal and a possible reduction in total cost is brought about by electrically-welding heads to bodies, the die-drawn stock itself is of much greater strength.

The following quoted from Kent's pocket book may be of interest in this matter:

"EFFECT OF COLD DRAWING ON STEEL."

1. Original bar 2.03" diameter, 30" long showed a T.S. of 55,400 lbs. Elongation of 23.9%.

2. Original bars reduced in compression dies (one pass) .094" showed T. S. 70420 lbs. Elongation of 2.7% in twenty inches.

3. Original bar reduced .222" showed T. S. 81,890 lbs. Elongation of .074% in twenty inches.

Tests of cold-rolled and cold-drawn steel made by the Cambria Iron Co. in 1897 (average of twelve tests):

	Elastic Limit.	T. S.	Elongation 8 In.	Reduction.
Before rolling.....	35,390	59,980	28.5 per cent.	58.5 per cent.
After cold rolling..	72530	79,830	9.6 "	34.9 "
After cold drawing..	76,350	86,860	8.9 "	34.2 "

In reference to the cap screws made with the U. S. Standard or Franklin Institute heads, we believe this to be an important item, practically as the small bearing shoulder, under an ordinary cap-screw head, which actually becomes less as the size of the screw increases, is very often crushed or burred in use, and the unhandy size of the head of the ordinary cap screw, especialy when desirous of using a solid or drop-forged wrench, is a matter that all machinists and engineers have met with.

There never was, we believe, any valid reason, other than economy of stock, and labor of removing of metal for making these heads so small, though probably before the application of electrical welding the cost would have been prohibitive. An electrically-welded head and body, when made of die-drawn stock, is apparently a great gain in both economy and strength.

In view of the points already mentioned, and the efforts the Cleveland Cap Screw Co. have made in the manufacture and introduction of an improved product for the use of machine

builders, in the strength, handiness, finish, etc., the Committee would recommend the award of the John Scott Legacy Premium and Medal to David J. Kurtz, the originator of the method.

Adopted at the stated meeting of the Committee on Science of the Arts, held Wednesday, January 4, 1905.

Attest : WM. H. WAHL, *Secretary.*

THE GOVERNMENT SEEKS THE CO-OPERATION OF EXPERTS.

In the business world it has long since been the day of the expert. In public affairs the day of the expert is also dawning. The need for special training and for technical advice is felt in every branch of the Government service, and it is one of the most healthful signs of the times that those who direct the great work of the Government's civil bureaus are seeking to do it by the light of the latest scientific reasons. It was in harmony with this general spirit that a meeting was recently called in Washington by the Secretary of the Interior, his invitation being indorsed by the Secretary of Agriculture. This meeting was a conference of prominent engineers and officials of the Geological Survey and of the Bureau of Forestry with certain gentlemen high in railroad and engineering circles. Problems connected with the testing of structural materials, such as stone, cement, coal, and timber were discussed. Both the Geological Survey and the Bureau of Forestry are maturing plans for extensive work in testing the character, durability and strength of these materials. With the desire of securing the coöperation of those who make practical use of the materials and who best understand the requirements which they have to meet this meeting was held.

Besides the chiefs of the Geological Survey and the Bureau of Forestry, representative superintendents, engineers, and chemists of the principal great railroads of the East were in attendance, together with representatives of the American Society of Civil Engineers and the American Society of Cement Users, the editor of the *Cement Age*, and the chief engineer of the City of Philadelphia.

It is hoped that the result of this conference will be the establishment of a continuous advisory board of experts who will assist the Geological Survey and the Bureau of Forestry in the conduct of these tests. Plans similar to this have long since been indorsed by European countries, but no such coöperation between Government and a body of experts has ever before been effected in the United States. It is hoped that the experiment will be of great practical benefit to both public and private interests.

THE DOMINION GOVERNMENT has appropriated $15,000 for the purpose of making experiments with the electric process of smelting ores and manufacturing steels. The experiments will take plate at the plant of the Consolidated Lake Superior Company, which concern will supply 400 hp. for four months without charge.

Goldschmidt's System of Alumino-Thermics.

[Being the Report of the Committee on Science and the Arts on the Invention of Dr. Hans Goldschmidt, of Essen, Germany. Sub-Committee, Dr. H. F. Keller, Chairman; A. E. Outerbridge, Jr., H. G. Morris, James Christie, G. H. Clamer.]

[No. 2321.]

The Franklin Institute, acting through the Committee on Science and the Arts, investigating the subject of "Alumino-Thermics," a system devised by Dr. Hans Goldschmidt, of Essen, Germany, reports as follows:

The subject of this report has been repeatedly brought to the attention of our members both at stated meetings of the Institute and of its Chemical Section. Scientific and popular accounts, profusely illustrated with experiments, of Dr. Hans Goldschmidt's inventions have been given by members of the Institute, as well as by representatives of the inventor, so that it would seem quite superfluous here to enter into a detailed description of the process or to enumerate all the various applications that have been devised or proposed by the inventor.

The sub-committee further deems it advisable to confine its report to "Alumino-Thermics" proper; that is to say, to that part of Dr. Goldschmidt's work which concerns the production and utilization of very high temperatures by means of mixtures of aluminum and with a metallic oxide, such as oxide of iron. Not only have his efforts along these lines led to the most important practical results, but they embrace all that (in the sub-committee's opinion) is novel in the process.

Of the several patents granted to the inventor by the United States Patent Office between March 16, 1897, and August 4, 1903, three relate to the joining of metal pieces, or welding, and one to a process of manufacturing homogenous metal castings. The numbers and dates of the patents are as follows:

Number.	Date.
735,244	July 21, 1899.
729,573	June 2, 1903.
717,840	Jan. 6, 1903.
733,957	July 21, 1903.

The heat-producing material, known as Thermit, is now manufactured by Dr. Goldschmidt at his Essen works on a considerable scale. It consists of an intimate mixture of finely divided aluminum and oxide of iron (or other metallic oxide), the ingredients being present in chemical proportions—

$$2Al+Fe_2O_3=2Fe+Al_2O_3.$$

When this thermit is ignited in one spot, the reaction proceeds with marvellous rapidity through the entire mass without any further supply of external heat. Owing to the high temperature of ignition of thermit, the reaction is started either with a bit of burning magnesium ribbon, or, better, by the aid of a special ignition powder, consisting of peroxide of barium and aluminum powder.

The extraordinary thermal effects of the reacting mass (its temperature is said to approach 5400° F.), are due to the sudden disengagement of a vast quantity of heat in a relatively small volume of material. The only products are metallic iron and oxide of aluminum, which retain practically the entire heat of the reaction, and, being liquid, separate into two layers—the metal below and the alumina-slag on top.

As already stated, the principal use of thermit is in joining metal pieces, especially of iron and steel.

Thermit-welding has been successfully applied during the past four years in a great number of cases, for some purposes on an extensive scale. Conspicuous among these uses of thermit is the welding of street railway rails at the joints for the construction of continuous track. Many thousands of such welds have been made in England and Germany, and, while the method has not so far found introduction on a large scale in this country, it has been adopted and employed for repairs of the more costly and complex parts of tracks, such as crossings, switches, etc., with excellent results, as one of the members of the sub-committee can attest from personal experience. Special mention should be made also of an advantage in thermit-welding in that it dispenses with all bulky equipment, for it requires only a few simple appliances in addition to the thermit itself. Of the latter the Goldschmidt works now supply "welding portions," each containing the quantity required for one weld. In the case of rail ends, the weld is made by bringing

the molten iron resulting from the reduction of the thermit in direct contact with the rails, so that it will adhere to the parts to be joined, and thus unite them.

Another method of thermit-welding, applicable to wrought-iron pipes and angle iron, depends entirely upon the heat obtainable from thermit, the reduced iron not being allowed to adhere to the welded parts. To this end it is only necessary to apply the molten thermit mass in such a way that the slag (alumina) first comes in contact with the cool surface of the articles so as to form a protecting layer, and thus prevent the metal which follows from adhering. While the ends of the pieces are brought to the welding temperature, the weld is produced by aplication of pressure, but without disturbing or changing the section of the welded parts.

Thermit welding has also proved most valuable as a means of repair in break-downs of machinery. Many cases have been reported where otherwise exeedingly difficult, if not impossible repairs were made by its means, and so far as the sub-committee is able to ascertain, with remarkably uniform success. It is to be noted in this connection that the repairs which have been made by the aid of thermit include smaller operations, such as replacing a tooth in a steel wheel, as well as the welding of very large pieces, like the stern-posts and crank-shafts of trans-Atlantic steamships.

Still another ingenious application of the thermit reaction is in preventing the formation of cavities in large steel castings. A box of specially-prepared, so-called anti-piping thermit, attached to an iron rod is pushed into the ingot, just as a crust is beginning to form. The heat produced is sufficient to keep the metal liquid where the piping occurs and allows more liquid metal to be poured in to fill the cavity.

It is the opinion of the Sub-Committee that the invention of thermit and its application in welding and casting metals, constitutes a great step in advance in the production of utilization of high temperatures. While it is recognized that Dr. Goldschmidt was not the first one, either to observe or to apply the heat liberated in this reduction of metallic oxides with aluminum, he must be credited with having developed the manufacture of thermit, with the practical application of the enormous heat energy stored in this product, and with extraordinary per-

severance and resourcefulness in bringing these inventions to commercial success and thereby creating a new industry.

The chief obstacle to the more extended use of thermit in this country has been the rather high price of the article with the added import duty. It is to be expected, however, that this barrier will be removed as soon as thermit can be supplied by an American factory.

The sub-committee unanimously recommends the award of the Elliott Cresson Medal to Dr. Hans Goldschmidt for his inventions in "Alumino-Thermics," by the Franklin Institute.

Adopted at the stated meeting of the Committee on Science and the Arts, held Tuesday, June 21, 1904.

Attest: WM. H. WAHL, *Secretary.*

NICKEL STEEL.

Nickel steel has of late received special attention, and has been investigated by engineers in relation to its usefulness as a structural material. For many years metallurgists have experimented on the effect of the addition of special metals to steel with a view to increasing the ultimate strength and elastic limit of the steel without proportionately decreasing its ductility. So far, as a special structural steel, nickel steel is the only one which has proved satisfactory.

Nickel steels of varying carbon and nickel have been successfully used during the last fifteen years for marine and stationary engine shafting, locomotive axles, piston rods and crank pins and a wide variety of forgings and castings for parts of machinery. Its application for the manufacture of armor plate since 1890 is well known. It has recently been adopted, especially in this country, for gun forgings. It has been proposed for structural work before, but is now actually used for bridge construction in the eye bars for the Blackwell's Island cantilever bridge across the East River, New York City, and may take an important place as a structural material for long-span bridges.—*Iron Age.*

THE BARNARD MEDAL has been awarded this year by Columbia University, New York City, to Henri Becquerel, of Paris, France, in recognition of his important discoveries in the field of radio-activity and for his discovery of the dark rays from uranium. The award comes once in five years, and has been made on the nomination of the National Academy of Sciences.

A LARGE VIADUCT is to be constructed across the river Indus at Khushalgrah, one of the largest rivers in India. The bridge is to be of the double-deck type, carrying the railway on top, with the roadway beneath. It will have 470-foot cantilever span and an "anchor" span of no less than 603 feet.

CHEMICAL SECTION.

*Mica and the Mica Industry.

By George Wetmore Colles.†

[The subject is treated in eight principal captions: Migerology, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The present instalment includes the first of the above captions, dealing with the characteristics of the various species of mica.—The Editor.]

The object of this paper is to present in connected form whatever may be of interest on the subject to those industrially or commercially interested in mica. Unlike the grander mineral products, such as coal, iron and copper, concerning which volumes have been and are constantly being written, the mineral mica has not yet received any treatment at all from writers, other than a local, partial or superficial one. Nor is it strange that this should be the case; for it is well within the memory of living men that mica as a commercial product has emerged from a condition of too diminutive proportions and too localized to be called an industry, to the occupation of a very respectable place in the industrial world, and one of ever-growing importance.

In approaching the subject of mica the investigator is immediately confronted with an obstacle which is apt to discourage him at the start. I refer to the fog-bank of mystery which overhangs the whole subject, and which may prove well nigh impenetrable to one not himself engaged in the industry as either buyer, seller or miner. You ask why? and echo answers wherefore. Perhaps it is a relic of the North Carolina secretiveness spread over the country at large. As well ask a Carolina mountaineer about the moonlight stills of his neighborhood as about the mica mines which they intersperse. But I do not refer merely to the miners. The large dealers and users refuse information of any kind, and a few sporadic exceptions

*Read by title. †Copyright, 1905, by George Wetmore Colles.

seem only to prove the rule. Two of these exceptions (both in Canada) deserve special mention. I refer to the Blackburn Brothers, to whose mine in Ottawa County, Quebec (the largest in the Province), I not only was given access, but assisted in my examination of the entire property, and shown every courtesy; and the General Electric Company, of Schenectady, N.Y., to whom I am indebted for an equal degree of courtesy and the privilege of a tour of inspection through the great Lacey mine, one of the richest, if not the richest, mine in the world. To these firms I desire to express by thanks.

It shall be my main thesis to show, in the following pages, that the mineral mica, industrially considered, embraces not one, but rather *two* distinct mineral products; and that the mica *industry*, as a whole, comprises in reality a group of several distinct industries which have little in common.

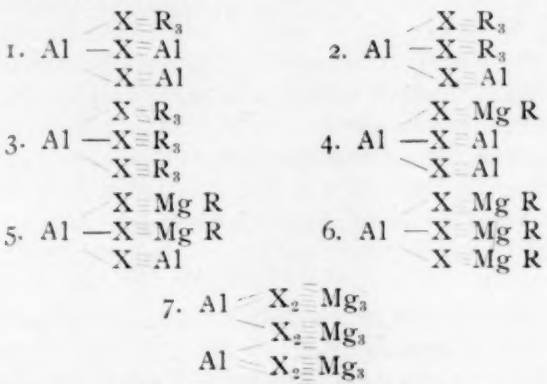
I. MINERALOGY.

The term mica embraces a group of minerals all of which have certain very marked characters in common. Chemically speaking, they are hydrous, but not strictly speaking hydrated,* compound silicates of the base aluminum in combination with potash, soda, iron, manganese, magnesia or lithia; or rather of several of these bases, for they are practically never found alone. Lime, baryta, strontia, and some of the other elements* occur occasionally in small quantities, but ought to be looked upon as accidental and as not properly belonging to the mica group. In addition, fluorine generally enters to some extent (from nothing in most muscovite to a maximum of 9 per cent. in the lithia micas) probably combining with one of the metallic bases to form a compound radicle. Until very recently

*I here use the term *hydrous* to designate rocks which contain the elements of water; *hydrated* to designate those having water of crystallization so called, that is, water for which a place cannot be found in a rational chemical formula.

*Rubidium and caesium accompanying lithia; chromium accompanying manganese; boron, titanium, copper, chlorine, and even carbon in one specimen of muscovite, are enumerated in the analyses collected by Dana; also vanadium, the principal constituent of *roscoelite*, a mica occurring in auriferous quartz in California.

mineralogists have been at a loss to reduce the micas to any satisfactory common formula, which would be found applicable to them all, as the rather futile hypotheses of Tshermak demonstrate; but the studies of F. W. Clarke* have shown that this is possible without too great complication. This formula is $R_{3n}Al_{4-n}(SiO_4,Si_3O_8)_3$ in which "n" has any integral value from 1 to 3, and R is a univalent radicle. This formula when expanded may assume any one of the following forms: $R_3Al_3(SiO_4, Si_3O_8)_3$, $R_6Al_2(SiO_4,Si_3O_8)_3$, $R_9Al(SiO_4,Si_3O_8)_3$, or for a dyad radicle Mg replacing the monad R formulas 1 and 3 would of course be doubled. In graphic symbols the various compounds would be written as follows, representing by X the tetrad radicle SiO_4 or Si_3O_8:



The univalent radicles represented by R may be either the simple metals, such as Na or Li; or the compound radicles MgF, MgOH, AlF_2 and AlO. The dyad radicles are Mg, Fe and Mn. The only triad radicle aside from aluminum is that of iron, which in that of the ferric state may replace a portion of the aluminum.

For such of the micas as are metasilicie, that is, contain an excess of SiO_2 above what is required for an orthosilicate, Clark resolves them into compounds of orthosilicates and polysilicates whose acid radicle is Si_3O_8, which is tetrabasic, the same as the radicle SiO_4. Micas of this composition are termed by Clarke "phengitic," and this seems a reasonable

*Am. Jour. Sci., Volume cxxxviii, page 384, Volume cxl, page 410.

means of explaining their constitution by a rational formula.

The respective formulas for the separate species of the mica group will be given separately below.

A careful consideration of the various kinds of mica, both from a chemical and physical standpoint, shows that they fall into two natural groups characterized (1) by the atomicity of the principal bases, uneven or even, here denominated respectively *perissad* and *artiad* micas (from the Greek words for "odd" and "even"); (2) by the character of these bases, alkaline or magnesian; (3) by the mineralogical environment in which they occur, granitic of pyroxenic; and (4) by their supposed mode of origin, igneous or aqueous. The principal kinds of mica may be thus classified as follows:

PERISSAD MICAS.

(Alkaline, Granitic, or Igneous Micas.)

Muscovite,	potash mica,	$H_2KAl_3(SiO_4)_3$.
Paragonite,	soda mica,	$H_2NaAl_3(SiO_4)_3$.
Lepidomelane,	ferric iron mica,	$(H,K,AlO)\ Fe_n(Fe,Al)_n(SiO_4)_n$.
Lepidolite,	lithia mica,	$KLi\ [Al(OH,F)_2]\ Al(SiO_3)_3$.
	that is:	$HKLiAl_3(SiO_4)_3 + K_3Li_3(AlF_2)_3Al(Si_3O_8)_3$.

ARTIAD MICAS.

(Magnesian, Pyroxenic, or Aqueous Micas.)

Phlogopite,	magnesia mica,	$(H,K,MgF)_3Mg_3Al(SiO4)_3$.
Biotite,	magnesia iron mica,	$(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$.
Zinnwaldite,	lithia mica,	$(K,Li)_3Al(OH,F)'_2Fe''Al_2(SiO_4,Si_3O_8)_3$.

It is of interest and importance to note that the crystallographic characters of the micas throw them into a corresponding and substantially identical classification; but with the possible exception of lepidomelane, which E. S. Dana places in the second class; but, as hereafter noted, there seems to exist considerable doubt as to what is meant by this term.

It is important to note that the names and formulae given above designate *types* rather than any sharply-defined chemical compounds, like calcite or quartz. It may be taken that the actual minerals never conform precisely to these formulas, and pass by gradations from one to another, so that it becomes diffi-

cult to delimit individual species. A large number of subordinate varieties have been described, which, however, are of no importance to our present purpose.

All the micas contain a small proportion of water, although sometimes falling to below one per cent. The actual amount is very variable. This water is to be considered water of constitution, that is, as constituting an integral part of the mica. This water is given off on heating under ordinary pressure.

Physical Characteristics.

The most striking characteristic common to all the micas is the quality of being easily cleavable into thin, elastic and generally transparent plates, and in this characteristic they find their economic usefulness. Mica is necessarily a crystalline mineral, and although many of the species, notably those of the second class, imitate the hexagonal system of crystallization (which possesses four axes, three of which line in one plane at angles of 60°) they all belong to the monoclinic system, having but three crystallographic axes, two of which make an oblique angle and are at right angles to the third. The micas of the first class, where they occur in sizes of economic importance, are found in blocks which are theoretically short rhombic prisms of 60° angle, though practically this form is obscured by the rough exterior, due to their mode of origin. But in granite, where the crystals are limited to the area of a square inch, we find them as a pile of hexagonal plates with clean-cut edges, and these plates are often spread apart at one side, so as to give a plumose effect, and leaving voids in the rock. In micaceous, schists and gneisses, mica occurs as individual scales (frequently of sedimentary origin) and in irregular small masses. There are many other forms of minor importance, which have been found in various rocks.

The natural form of micas of the second class is a hexagonal prism, the sides of which are, however, as a rule, unequal. The axis of the prism in each case is the oblique crystallographic axis, and the cleavage plane for the plates is that of the other two axes or base of the prism. There seems to be no practical limit to the possible thinness to which the plates can be split, other than the physical possibility of splitting them. Plates

are easily obtained one-thousandth of an inch thick, and have been split, although not in plates having any considerable extension, to a thickness of three hundred-thousandths of an inch —about one-thirtieth of the thickness of ordinary tissue paper.*

That mica has a very strongly characterized polarity can be readily observed by striking a mica plate with a dull-pointed instrument on a yielding surface, which will cause the mica to become fractured. The lines of fracture extend in one or more of three principal directions, which make angles of 60° with

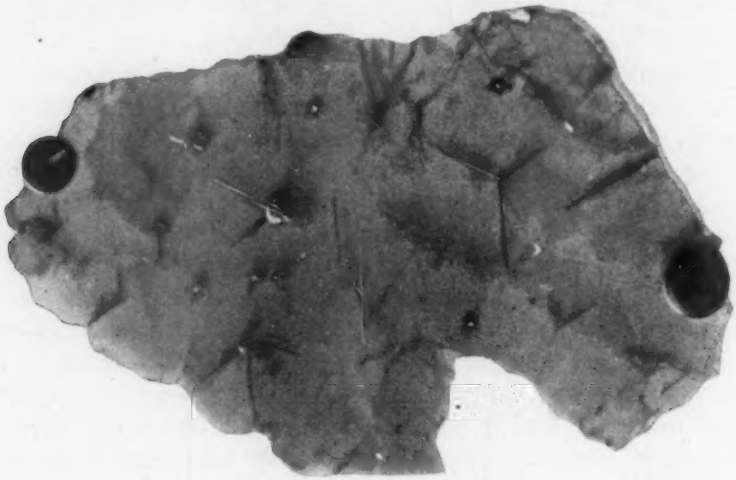


Fig. 1. Percussion-figures in muscovite.

each other and are perpendicular to the crystalline edges of the plate, and one of which is parallel to the clinopinacoid plane (the plane of symmetry of the crystal); or in one or more of three secondary directions, which are parallel to the edges of the crystal and bisect the angles formed between the first. When complete a six-rayed star, called the *percussion figure*, is produced, although often only two or three rays appear.*

A distinction is often made between a percussion-figure hav-

*According to Jefferson & Dyer in Trans. Am. Inst. Elec. Eng'rs, 1892.

*A simple way of producing a percussion figure is to take a wire nail, hammer the point upon an iron surface so as to dull and round it off, place a mica plate not exceeding one-sixteenth of an inch in thickness on a sheet of paste-board, wood, or other yielding surface, place the point of the nail on the mica plate and give it a light blow with the hammer, sufficient to fracture the plate slightly.

ing one of these sets of rays, and a *pressure figure* having the other set. By repeated experiments, however, I have not been able to discern any definite distinction of this sort. Rays produced by pressure generally correspond with the rays produced by percussion. In Figure 2 is reproduced photographically a

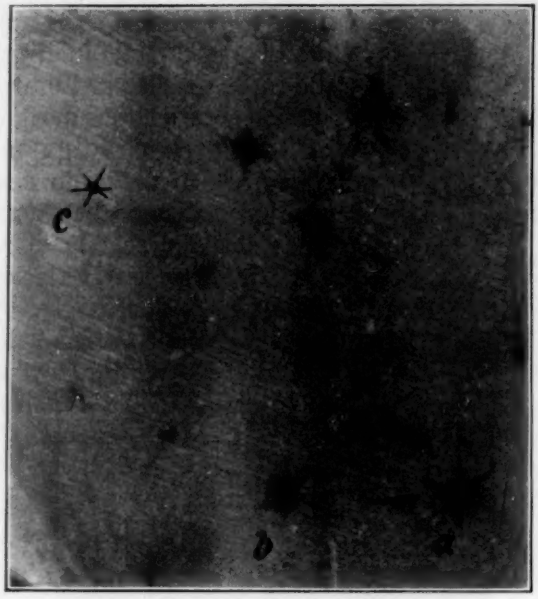


Fig. 2. Percussion-figures in muscovite. × ⅔

plate of mica having three asterisms, a, b and c; *a* and *b* both have rays of the first set, although *a* is a percussion-figure and *b* a pressure-figure, while *c* is a percussion-figure and yet has rays of the second set. The three sets are all included within a circle of less than one inch diameter. Note also a single secondary ray (horizontal on the right) in the asterism *a* bisecting the angle between two of the primary rays.*

Another indication of the strong hexagonal polarity of mica is seen in the ruling and striation which often occurs in one or more of the three *secondary* directions, *i. e.*, parallel to the edges

*It is not easy in practice to show the asterism in the softer micas, because the instrument, instead of cracking the plate, simply pierces a hole therein. The more brittle the mica the clearer will be the asterism.

of the crystal. The striations may be excessively fine, so as to require a glass to distinguish them, and show as fine, opaque lines as if due to parallel scratches. Inclusions are also frequently arranged with their principal directions parallel to those of the mica, as exemplified by the quartz crystals in Figure 3 and the rutile needles in Figure 4.

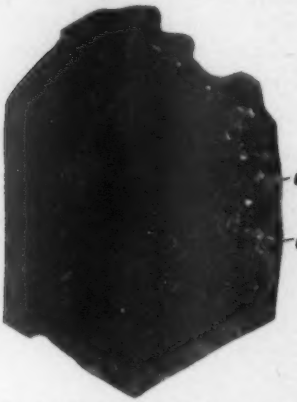


Fig. 3. Black Mica with hexagonal quartz crystals (as *a*) traversing and honeycombing the plate.

Such polarizations mark the traces of secondary cleavage or gliding *planes*, which make an acute angle with the planes of the plates.* These planes can be readily discerned on the straight edge of a thick plate. To them also is due the fact that mica cannot be cut smoothly with a knife-blade or saw held perpendicular to the surface of a plate. No matter how sharp the

Fig. 4. Black Mica (biotite) with rutile(?) needles. ×2. Note that needles are oriented at angles of 60 deg. (principal directions), but a few bisect these angles (secondary directions).

cutting edge may be, a jagged and torn surface always results.

The micas are all of a very soft nature, having a hardness va-

*These planes are inclined about 67 deg. to the principal cleavage plane.

rying from two to three on the mineral scale; that is, between gypsum and calcite. They can readily be scratched with iron or steel, and even with the finger-nail in some cases. The granitic micas are harder and more brittle in character than the pyroxenic and also slightly less cleavable—they cannot be split so neatly, cleanly or thinly.

Most kinds of mica are practically infusible in ordinary heats. Before the blow-pipe some of them, especially the lithia micas, are fusible with difficulty, yielding up a portion of their water. A very intense heat, as that of the electric arc, will cause the mica to whiten and crumble locally, and even a low degree of heat sufficiently prolonged, as in a stove or furnace wall, causes the mica to lose gradually its elasticity and become brittle and friable. The softer pyroxenic micas are more easily decomposed by water than the granitic. Mica has an unctuous or talc-like feel, which is most observable when ground, and renders it very useful as a lubricant. It is thought that this condition is due to the perfect smoothness of the laminæ, which is implied by the very perfect cleavage which it possesses.

Mica may be clear or opaque, but by clearness is to be understood that of a piece one-eighth of an inch thick, or less. Transparent micas in thick pieces appear opaque with a rich black luster, of whatever color they may be. The reason for this is to be looked for in the innumerable cleavage surfaces which reflect successive portions of the light until it is all reflected at a very slight depth. To ascertain the color of a piece of mica, it must be seen by transmitted light in a plate from one-sixteenth to one-eighth of an inch in thickness. Plates thinner than this often seem to be colorless. Opaque micas in thick blocks do not exhibit the rich black luster of the transparent micas, but have a metallic reflection. Such micas are opaque, or nearly so, even when seen in thin laminæ.

Muscovite is the commonest of all the mica types, and it is variously known as potash mica* and biaxial mica, and form-

**Potash* mica, because there is no other base to distinguish it by. It contains no more potash than other micas. All micas (except paragonite, a semi-mica) contain from 4 to 14 (generally 8 to 10) per cent. of potash; but one specimen of muscovite is cited (No. 32 on p. 618 of Dana's Mineralogy, 6th Ed.) which contained none at all, its place being taken by 4.17 per cent. of *lime*. It was still muscovite, apparently, and not margarite, as theoretically it should have been.

erly as muscovy glass, from which its technical name has been derived. The clear kind is known to the trade as "water mica," and this, as a rule, contains no iron, but much of the large-sized muscovite is unfortunately colored to some extent, which detracts greatly from its value. It is often, moreover, streaked, which still further decreases its value. The colors are apple green, dark olive green, also yellow, gray, brown and, according to E. S. Dana, violet and rose-red. It seems to pass over indefinitely into the iron mica which is herein termed lepidomelane. A great number of varieties have been specified which connect this type of mica with others and with different minerals, but which are of no importance for the present article.

Paragonite is a soda mica, or semi-mica, corresponding precisely to muscovite in composition, and occurring in a few places on the continent of Europe, but of no importance to our present purposes, as it occurs only in massive form or minute scales.

Euphyllite is a sodium-potassium variety, intermediate between paragonite and muscovite, having a laminaceous structure, but imperfect cleavage.

Lepidomelane is a name of somewhat uncertain application, but here designating the type ordinarily found in granitic rocks and their derivatives is a similar environment to muscovite. This mica has been termed biotite by most authors,* but it is certain that it is very different in its physical characters from the biotite found in the magnesian rocks, and resembles muscovite in everything but color. According to William B. Phillips,* Dr. F. A. Genth states that he has never seen biotite in mica veins (meaning the pegmatite dikes), which would indicate that he characterized the mica in question as merely a discolored variety of muscovite. It may be that the black mica which is of frequent occurrence in granites is really biotite and a ferromagnesian mica, in which the iron is generally in the ferrous

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*J. D. Dana (Manual of Geology, 3d Ed., p. 71) for example, classes "biotite" (= lepidomelane) as a "potash-mica;" this may be offset against the classification by his son, E. S. Dana (Descriptive Mineralogy, 6th Ed., § 462), of biotite as a magnesia mica.

*In Engineering and Mining Journal, April, 1888.

condition; but this mica is always of small size and accompanied perhaps with other amphibolic magnesian minerals, like augite or hornblende, while the pegmatite does not, so far as I know, contain these minerals. Lepidomelane, as shown by the formula, is of exceedingly complex besides very variable constitution, but characterized by the predominance of ferric iron and general basic qualities. It is in color usually black and somewhat brittle. It is inferior to other micas for electric purposes, and unsuitable for almost all others.

Lepidolite is a lithia mica, containing 4 to 6 per cent. of that base, as well as a large percentage (5 to 8 per cent.) of fluorine. It is almost always associated with muscovite and often crystallizes on or is intercrystallized with the latter. It appears to be the principal product of the Indian mines of the Hazaribagh district, in Bengal, and is highly esteemed as an electric mica for its toughness, flexibility and freedom from flaws, and is also apparently the kind almost exclusively used (at least until recently) in Europe for glazing purposes. It is generally of decided color—rose-red, purple, violet, gray, lilac, brown or yellowish; but also found colorless. In luster and transparency it is somewhat inferior to muscovite, but in thin sheets is quite transparent. It is notable for being the most important and practically the only commercial ore of lithia.

Phlogopite is the characteristic type of what is known to the trade as amber mica. It is, as a rule, of a marked and characteristic amber color, varying to yellow brown, greenish, etc. Commercially, three distinct varieties may be specified, to wit: (1) clear amber, transparent, soft; (2) mottled, medium in hardness; (3) milky, hard, opaque. The milky variety has a sheen like silver, for which it might readily be mistaken at first glance. The several grades are valued in the order named, the softest being the most useful for electric purposes. The appearance of milky mica is apparently due to fine mottlings which cover its surface, as can be seen by examining a thin lamina under a glass. These mottlings are similar to those of the mottled variety, except in their minuteness; they are irregular, whitish blotches—sometimes, perhaps, developing into minute striations, but not necessarily so.

Biotite is a ferro-magnesian mica, a part of the magnesia being replaced by ferrous iron, therefore of more general occurrence

than the pure magnesia mica. It is now apparently little used, probably on account of the abundance of the amber mica, which renders it unprofitable. This discrimination against biotite is believed to be largely based on prejudice. Biotite in large crystals has a luster of great brilliancy and irregular lines and spots or iridescent reflection frequently cover the surface.* I have seen immense plates of brilliant black biotite without a flaw of any kind; but it must be admitted that it is very apt to become rust-streaked and rotted in the ground, owing to the oxidation of the iron to the ferric condition, to which it is very subject when exposed to the joint action of water and air. A considerable number of varieties have been specified.

Zinnwaldite is a lithia mica corresponding to lepidolite, but containing, in addition to lithia and fluorine, from six to twelve per cent. of ferrous iron. In color it varies between various shades of brown, violet, yellow and gray. It occurs in only a few places, and is of no economic importance. Cryophyllite and polylithionite are specified as varieties.

Pholgopite and biotite are both distinguished from the other varieties by the comparative ease with which they absorb moisture and rot when lying on the surface of the ground. When found within a short distance of the surface they appear at first glance to be the same as other mica, but can be readily crumbled in the hand and crushed to a soft mud. The same is not true of the granitic micas, which may lie for an apparently indefinite period on the surface without noticeable change. This quality has an important bearing on the economic situation. The rock in which the granitic micas are found, on account of its hardness, makes their mining a task of great difficulty, but it often happens that the enclosing matrix is completely disintegrated leaving the mica intact, and where such is the case the extraction of mica is a matter of comparative ease. Again, the quality of mica in a pegmatic lode can be readily ascertained from surface indications; such, however, is not the case with the magnesian micas, as they change repeatedly in character

*These lines are also of frequent occurrence on amber mica. Their position is readily changed by rubbing the surface, and they may be wiped off altogether. The most probable explanation of these iridescent lines appears to be the presence of a hygroscopic iron salt in visicular inculsions.

with depth. Moreover, it is frequently necessary to perform a large amount of excavation before it can be learned whether the lode contains mica of value. Phlogopite and biotite are both completely broken up and dissolved by sulphuric acid, the silica being left behind.

Mineral Relations of the Mica Group.

It is of interest and importance, especially when we come to consider the origin and true nature of the micas, to take a brief survey of the place occupied by them with respect to other minerals. At the outset let it be noted that the micas, besides blending with one another, pass in like manner by indeterminate gradations into other related and similar forms. As silicates, they stand midway between the anhydrous silicates on the one hand, of which the feldspars are examples, and the hydrated silicates on the other, of which the zeolites are most characteristic. The feldspars, like the micas, are compound silicates of aluminum and another metal, ordinarily an alkali. These contain no water, and consequently can give off none by heat. The zeolites, on the other hand, also compound silicates of aluminum and an alkali or alkaline earth, invariably contain the elements of water in the molecule, and this water is given off on heating. The feldspars are characteristic of igneous rocks, forming an almost invariable constituent of lavas and intrusive rocks. The zeolites are considered to be secondary products of the same rocks, occurring in igneous rocks such as trap and ordinary lava, but have been formed by the action of water since these rocks became cold. Likewise, in hardness, the micas lie between the harder feldspars and softer zeolites.

From another side we have the clays, the base of which is kaolin in pure form, consisting of the mineral kaolinite. The clays are hydrous *aluminum* silicates, and are secondary products of feldspathic rocks formed by the leaching out of the soluble bases, potash and soda.

The three groups most closely related to the micas, however, are (1) the vermiculites, or hydrated micas, (2) the brittle micas, and (3) the chlorites.

The vermiculite group comprises derivation products of the true micas formed by the latter taking up water, and they have

a very similar appearance with a more or less perfect cleavage; but the plates are soft, imperfect and non-transparent, and have not the toughness of true mica.

Among the brittle micas the principal form is margarite, whose chemical formula conforms to the theoretical general formula given for mica, except that the alkaline base is calcium, which is not a constituent of the micas proper. This semi-mica possesses also brittle, non-transparent plates.

The chlorites resemble most closely the second class of micas in being compound silicates of aluminum, magnesium and ferrous iron—the last two replacing one another in indefinite proportions, and ferric iron also occurring in substitution for aluminum. The crystallization is similar to that of mica. Beyond the chlorites we approach the strictly magnesian and calcic silicates—epidote, pyroxene and amphibole. Among the best known magnesian silicates associated with these are hornblende, soapstone, talc, tremolite, asbestos and serpentine.

We see that the micas divide themselves clearly on the lines of feldspathic or igneous rocks on the one hand and pyroxenic or magnesian on the other, and it will be seen later that the distinction is fundamental, whether from a geological or economic standpoint.

Pinite is a name given to a number of soft, massive minerals, having indeed, no superficial resemblance to mica, but corresponding pretty closely to muscovite in composition,—alteration products of various silicious rocks. It is probably to be regarded as a massive, compact variety (of muscovite), usually very impure from the admixture of clay and other substances.* If opportunity were given to it to recrystallize under proper conditions, mica would doubtless result. This will serve to explain the origin of mica in many cases.

It is noticeable that all the more important of the minerals above enumerated—including orthoclase, feldspar, the zeolites, vermiculites, chlorites, margarites, kaolinite, serpentine, talc and pyroxene (but not amphibole), crystallize on the monoclinic system, and many of them are characterized by thin, hexagonal plates, and have other more or less close resemblances to mica.

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*E. S. Dana, Mineralogy, p. 621.

Artificial Micas.

It is interesting to note that many of the principal varieties of micas have been obtained artificially. By fusing various natural silicates (hornblende, actinolite, glaucophane, andalusite, garnet, etc.,) with the fluorides of sodium and magnesium, micas corresponding to biotite, phlogopite, muscovite and zinnwaldite were obtained. Khruschoff describes the formation of margarite, biotite and muscovite by fusing various bases with the constituents of lepidolite, and an excess of silica, alumina and alkaline fluorides. Vogt, of Sweden, also describes the occurrence of mica in slags. Notwithstanding this,

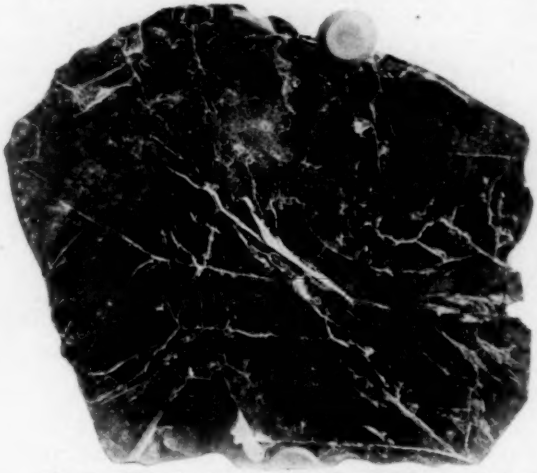

Fig. 10. Mica-plate heavily creased by earth forces. Much of the magnesian mica is found in this condition, and is, of course, worthless as sheet.

however, there is not the least likelihood of artificial mica being produced on a commercial scale at a profit. These experiments merely explain to us some possible modes of origin of natural mica.

Defects.

From an industrial standpoint the defects of a sheet of mica will, of course, depend on the uses to which it is to be put. The most general defect, however, which lessens the value of the mica for whatever purpose, is flaws. Although a sheet of mica may be several square feet in extent, flaws extending across it,

or through it, may render its value per pound even less than that of much smaller sizes. Generally speaking, the value of mica grows in proportion to its size, clear of defects, the smallest size of sheet-mica in commercial use being that which will cut in rectangular sheets 2x2 inches without flaws, and anything smaller than this being classed as scrap.

Flaws in a sheet of mica arise, generally speaking, from the stresses to which the crystal from which it was taken has been subjected while still in the ground, and which cause the same to be bent, folded, or creased, and thus give rise to cracks. A crack or crease extending across the plate may be said to divide the plate for industrial purposes at that point. The main task of the mica sorters, in sorting mica according to size, is to

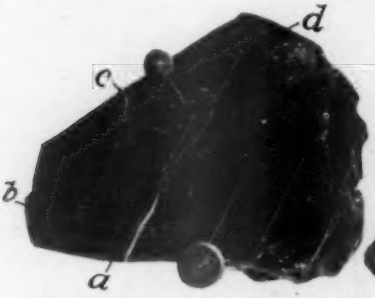

Fig. 11. Mica-plate creased on principal planes, making an angle of 60 deg. with the clino-pinacoid *a*. *b*, *c*, *d*, crystalline edges.

Fig. 12. Amber mica with intruded quartz laminæ, *a*, *b*.

quickly distinguish all cracks and other flaws and trim them away from the plate.

Inclusions give rise to another kind of flaw, which result in holes in the plate, and of course render that portion of it worthless. Small crystals of quartz or calcite may occur traversing the plates (Fig. 3); these were evidently in the crystal at the time it was formed, but, on the other hand, flat crystals are sometimes found between the plates, which were intruded after the crystal was formed. It is quite common to find films of massive quartz, as in Fig. 12, almost as thin as the mica laminæ themselves, projected between them. The quartz was *not* forced between the plates like a wedge, but was deposited in a void previously existing there.

Another variety of inclusions is minute crystals of black ox-

ide of iron, a very common feature of black granitic mica, and one which practically destroys its value, because they cannot be got rid of at a reasonable expense. If used for electrical insulation, they would form paths for the puncture of the plate; whereas for glazing purposes, they destroy its appearance. These crystals appear for the most part to arise from the iron carried by the mica itself. The iron micas generally, as previously indicated, are quite liable to defects, not only of this kind, but to similar ones, resulting from the vacillation of the contained iron between the ferrous and the ferric state. Rust streaks are of very common occurrence, and streaks, checks and other marks, also occur, which result from the irregular distribution of the iron, and naturally make it valueless for glazing purposes. For example, a plate of mica will be half black and half colorless divided along one of the lines of polarization; or series of black lines will occur parallel to one or more of the edges of the crystal.

Ruling (Fig. 13) is a common defect in the granitic micas, which likewise destroys the value for every purpose except grinding, of what would otherwise be mica of excellent quality. When a ruled block is split the marginal portions will fall away in ribbons parallel to one of the edges; or occasionally parallel to both edges ("double ruled") resulting in the latter case in small rhombs or lozenges (Fig. 14). The existence of this condition means simply that the crystal has been subjected to shearing forces, which have resulted in a partial cleavage along one or more of the secondary cleavage-planes of the crystal. This defect is most common in the granitic micas, and is one of the indications which go to show the conditions under which they were formed. That the necessary shearing stresses to produce this result should have arisen during the folding of the rocks, which followed the formation of the mica dikes, is almost a matter of course. Ruled mica is not found in isolated crystals in these dikes, but all the mica of the vein, or of a considerable portion of it, will be found in the same condition; and this applies not only to ruled mica, but to other defects likewise. All the mica

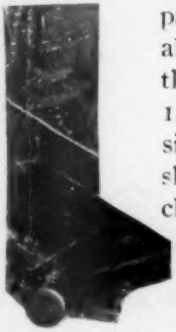

Fig. 13. Ruled amber mica.

at a given point is of the same general character, and suffers from the same defects.

Although ruling of this kind is not common in the pyroxenic micas, it is not uncommon to find the edges of crystals of the latter kind finely divided by parallel planes—so finely, in fact, that the substance of the crystal can be readily crushed into a fibrous material similar to asbestos, though, of course, of a coarse and brittle nature (Fig. 15). It seems, however, quite impossible that this fibrous condition should have been produced by strains extending through the mass of the rock, or, indeed, by any strains at all, as it is of isolated occurrence.

Fig. 14.
Lozenge of ruled biotite.

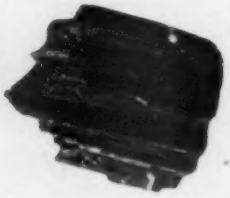

Fig. 15.
Fibrous mica (magnesian).

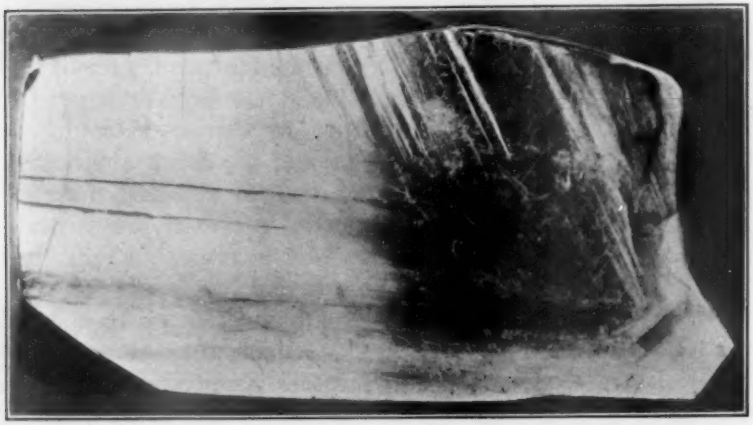

Fig. 16. A-mica (by transmitted light). For some reason a dark blotch appears over part of the thickened or welted portion, but does not extend over the remainder. No such blotch is visible to the eye. Presumably due to a pleochroic refraction.

Allied to ruling is the defect known as "A"-mica, which is mica having the edges of the crystals corrugated and of uneven

thickness for a considerable distance inwardly. The corrugations on two adjacent edges making an angle of 60° give the appearance of a letter A, without the middle bar; it would be more properly called "V-mica." As indicated by the section of the plate in Figure 16, a plate of A-mica will show a welt of increased thickness running through the corrugated portion. The internal plates do not extend beyond the inside of this welt and the welt itself may comprise strips of uneven thickness intercalated between the plates which extend across. Obviously this cannot be the result of pressure alone, and some other agency acting during the formation of the crystal must be relied on to explain it. A-mica, like ruled mica, is characteristic of the granitic varieties.

Wedge-mica is another common defect to which granitic micas are subject, but I believe it also occurs in a somewhat different form in the pyroxene formations, in which, however, it does not play an important part. A block of wedge-mica is thinner at one end than at the other, and the plates split therefrom are likewise thinner at one end than at the other, and some of the individual laminæ do not extend all the way across the plate. The mica of the Godfjeld mine, on the southwest coast of Norway, is of this character. The cause of this defect is somewhat mysterious, but it is undoubtedly to be looked for in the irregular action of the crystallogenic forces.

While specked mica is valueless for any purpose, ruled, A-, and wedge-mica, if not otherwise defective, have a value as scrap; but this value is not sufficient, as a rule, to make it pay to mine them. When a lode is found with mica thus defective, it is simply passed by. Specking, on the contrary, does not always become general, or prevent good mica from being taken from the same place; it may be confined to a limited region near the surface.

Color is a defect only for certain purposes, as for stove-glazing, and, when ground, for decorating purposes. Perfectly colorless mica bears the highest value for these purposes, although much of that which is used has some color, as for example, the ruby mica of India, and the somewhat smoky product of New Hampshire. The tints of these in thin sheets are not perceptible to the eye, but they do exercise a decided influence on the amount and quality of transmitted light. Mica

having a comparatively light tinge of green is deficient in quality for use as a decorative ingredient in paints.

[*To be continued.*]

THE PANAMA CANAL SITUATION.

Referring to the unfortunate complications that have arisen in connection with the commencement of the work on the Panama Canal, the *Scientific American* makes the following editorial comment:

"The most ardent advocates of the Panama Canal must admit that, admirably as the government has handled the matter of the purchase of the Panama Canal property, it has made something approaching to a pitiful fiasco in its attempt to commence actual construction of the canal. * * *

There is absolutely nothing in the Panama situation to prevent the application of the railroad methods of organization in carrying the work through. As far as the constructive features are concerned, it must be a one-man job; and we do not hesitate to say that there are not merely half a dozen but fully a score of civil engineers in America to-day, any one of whom is capable, if left absolutely untrammeled by unnecessary red tape, to take hold of the Panama Canal, enormous undertaking though it be, and pushing it through to completion within a specified time and for a specified cost, and with just as much absence of friction, delay, graft, bickerings, political interference, and all other petty and pure childishness of that kind, as similar works have been and are being carried through by these same men for the various railroads of this country to-day.

A cubic yard of earth, hard pan, or rock is about the same thing at Panama as it is in the Rocky Mountains or on the plains of Dakota. In Panama so many million tons of it can be dug up, blasted out, and carted away, with as much certainty as to cost as it can in the mountains or on the plains of the West. A single Chief Engineer of the Panama Canal, if given an absolutely free hand, can gather around him a staff of engineers just as efficient for their work as any he may have handled when building railroads in a more northern clime. The contractors are ready with their plant and appliances to do just as expeditious work at Panama as in Maine, Missouri or California, and the work they do will be measured up, appraised, and vouched for by the Chief Engineer and his subordinates with just as little "lost motion" and with as great dispatch as in the construction or rebuilding of railroads.

If the unfortunate experience of the government in its initial work on the construction of the canal has no other effect than to teach the above lesson, it will not have been for naught. The course of events suggests that the scheme of administration, as at present adopted, is greatly overelaborated and is so cumbersome that it will ever be in danger of breaking down of its own weight."

Stated Meeting, held Thursday, December 15, 1904.

Sources of Supply and Methods of Manufacture of Phosphates and Potash Salts.

By Edward B. Voorhees.

Director New Jersey Agriculture Experiment Station, New Brunswick, N.J.

[The author in this article gives a brief account of the various sources of supply of natural phosphates, especially in the United States. Also an account of the well-known Stassfurt deposits of potash salts.—The Editor.]

PHOSPHATES.

Of the mineral elements required by plants, phosphorus and potassium are of the greatest importance. The term "soil exhaustion" means the exhaustion primarily of these constituents rather than any of the other minerals that plants need. In the crops of cereals, hay, flax and cotton grown in this country, there are removed from the soil annually phosphoric acid equivalent to about 7,000,000 tons of super-phosphate, containing 14 per cent. of phosphoric acid, and an equivalent of 2,500,000 tons of muriate of potash containing 50 per cent. of "actual potash." Phosphates useful for the purpose of the manufacture of fertilizers, are obtained from two sources, organic and mineral. Organic phosphates consist chiefly of animal bone—this phosphate has been in use from very early times, though it is within the last century that it has been used in a rational way. The very good results derived from the use of bone, both raw and dissolved, have encouraged its wide use, and often in preference to the phosphates from mineral sources. Mineral phosphates, first discovered in England in 1845, were called "Coprolites." Other deposits have been found since in various parts of Europe and other countries, notably the "Bordeaux Phosphates," in France, "Phosphorites," in Spain, "Apatites," in Norway, "Phosphatic Guanos," in the West and East Indies, and in the islands of the sea, and deposits of greater or less value in Japan and Algeria; in fact, in nearly every country of the globe are found deposits of phosphates useful in the manufacture of fertilizers. Nevertheless, the most abundant and richest deposits are found in America, and

mainly in the United States. The deposits of apatite in Canada, of purely mineral origin, and discovered in 1867, for a time served as a considerable source of supply, but owing to the difficulties in mining, and the expense of separating and handling the phosphates, the output, notwithstanding its high quality, has rapidly declined since 1884. The South Carolina deposits, near Beaufort, S. C., first exploited in 1867, and continuously worked since; the Florida deposits, discovered in 1888, and the extensive Tennessee phosphates, discovered in 1893, have been rapidly developed and are now the chief sources of supply of phosphates of the finest quality. These deposits are not only extensive, but are easy to work, particularly those of Tennessee, and especially well adapted for the manufacture of super-phosphates.

The South Carolina rock phosphate occurs in the form of nodules, ranging from the size of a pea to the size of a man's head, and is found both upon the land and in river beds. On the land, the phosphate-bearing stratas are usually covered with sand to a depth of from six to ten feet, and the stratas vary in thickness from one to several feet. The mining on land is now accomplished by means of steam shovels, which remove the over-burden first, when the phosphate, together with the materials associated with it, is screened and washed, then kiln-dried or burned, in order to remove from it the adhering clay. In the river beds the phosphates are mined by means of a dredge, which scoops up the phosphate, which is then washed and dried, as in the case of the land rock. The composition of the rock varies from 55 to 60 per cent. of bone phosphate, and about 6 per cent. of iron and alumina.

In Florida, the phosphate exists in three forms, namely, rock or boulder phosphate, found in ledges; pebble rock, found in mounds or beaches, and soft phosphate, found in cavities or pockets. These also vary in composition; the boulder frequently reaches as high as 80 per cent. of bone phosphate, and $2\frac{1}{2}$ per cent. of iron and alumina; the soft phosphate contains about 65 per cent. bone phosphate, and 6 of iron and alumina, and the pebble phosphate 62 per cent. bone phosphate, with 3 per cent. iron and alumina. The mining of the Florida phosphate is practically the same as carried out in South Carolina, except that where the over-burden is heavy and there is an

abundance of water, it is removed by means of water—the hydraulic system, therefore, being much more economical of labor.

The Tennessee phosphate does not occur in the form of nodules, but in seams and layers between limestone rocks, and there are three well defined forms, the blue, containing 60 to 70 per cent. bone phosphate, with 2½ per cent. of iron and alumnia; the white, or rose color, containing 82 to 85 per cent. of bone phosphate and very low in iron and alumnia; the brown, ranging from 75 to 80 per cent. of bone phosphate and from 3 to 7 per cent. of iron and alumnia. The mining of the blue and white rock fields is by tunneling, through horizontal entries from the out-crop. The brown rock is entirely open-cut work. The top, or over-burden, is first removed, and then the rock, which lies in layers, is loosened with picks, and handled with forks. The rock when mined is usually sun-dried, or if very dirty, washed and burned.

The various phosphates, both organic and mineral, are in their natural condition insoluble, and thus are not in a condition to quickly supply the needs of plants, nor to meet all the conditions of cropping. Investigations have revealed, however, that for many crops and under many conditions, the organic phosphates, as animal bone and the mineral phosphates, when finely ground, do serve to supply the phosphoric acid rapidly enough to meet all demands. When such is the case, the necessity for further treatment is not apparent, though because these conditions are limited, it is not likely that a very large demand will be made for phosphates in their insoluble form, and the only treatment of which is their fine sub-division. Very early in the history of their use, therefore, studies were made of methods of treatment which would change the insoluble and slowly available phosphates into more quickly available forms, with sulphuric acid, that the reaction resulted in forming a monocalcic, or soluble phosphate, and sulphate of lime. This treated product is the super-phosphate of commerce. At present, therefore, a large portion of the organic phosphates, and practically all of the mineral phosphates are changed into super-phosphates before being applied to the land.

The value of a phosphate from the standpoint of the fertilizer manufacturer, depends both upon its content of phosphate

of lime, as well as its content of iron and alumina. The higher the percentage of iron and alumina, the less valuable, for the manufacturer of super-phosphates, as the presence of these minerals require not only that a larger amount of acid shall be used in the treatment of the phosphate, but the resultant product contains less soluble phosphoric acid, and is more liable to contain a higher percentage of the reverted or the dicalcic form.

The value of a phosphate when used in its natural state, is based upon its content of phosphoric acid, but the value of a phosphate for the manufacture of a super-phosphate depends both upon the amount of phosphoric acid contained in it, and the amount and kind of other constituents associated with it. Phosphates which contain considerable amounts of iron and alumina, are not well adapted for the manufacture of super-phosphates, and no method has yet been perfected which will convert these products into as valuable superphosphates as those derived from phosphates containing minimum amounts of the foreign minerals. Various methods of treatment of phosphates unsuitable for super-phosphates have been used, which, while not making them as valuable under all conditions as super-phosphates, materially increase the availability of the phosphoric acid. Still, these phosphates are better adapted for use as phosphates than as constituent parts of a manufactured fertilizer, of which super-phosphates or acid phosphates now constitute nearly one-half the total weight. A prejudice existed for a long time against super-phosphates, because it was believed that they contained free acid, and would thus injure the land. This has now largely passed away, though this feeling, together with the fact that the continual application of super-phosphates without proper association with other substances does have a tendency to change the physical character, and to some extent the chemical character of the soil, has given rise to the demand for neutral phosphates, those in which there can be no possibility of acid being present. These, however, have not yet been perfected, and the chances are that a broader knowledge of the composition and methods of use of the super-phosphates will rather encourage their use than increase the demand for products of another sort.

POTASH SALTS.

Potash is another constituent that is liable to become exhausted from most soils, though it is not so generally deficient as phosphorous, and is not so liable to be carried away from the farm, because it is contained more largely in the straw than in the grain, and is thus not exported from the farm in the sale of products. It, however, has a wide use, and practically the only source of supply at the present time is the Stassfurt mines, in Germany. These mines were discovered in 1857, and the first factory was established in 1861. There are now twenty-three mines, and the output exceeds 3,500.000 tons annually. This deposit of potash is supposed to have been derived from the evaporation of sea water, hence the deposits in their crude form contain other salts than potassium. These salts are found in well-defined layers from 1,200 to 2,000 feet below the surface. Kainit, containing about 12 per cent. of actual potash, and sylvinit, containing about 16 per cent. of potash, are practically the only crude forms used directly upon the land, or in the manufacture of the mixed fertilizers. The main supply for this purpose consists of the high-grade salts, muriate of potash, which is obtained from carnalite, by boiling with magnesium chloride and concentrating the solution and crystallizing and washing away the impurities. The process generally used in the manufacture of double sulphate and high-grade sulphate is to concentrate a solution of kainit, when, if allowed to stand, the double sulphate of potash and magnesia will crystallize out, forming the double sulphate. The high-grade sulphate of potash and of muriate of potash, which solution when concentrated, and the salt allowed to crystallize, form pure sulphate of potash.

In the manufacture of mixed fertilizers, super-phosphate usually constitutes more than one-half of the total weight of the mixture, while potash is usually contained in much smaller amounts owing largely to the fact of the high content of actual potash contained in the concentrated mixture. The double sulphate contains 26 per cent. of actual potash, the high-grade sulphate and muriate of potash about 50 per cent. actual potash, thus requiring much smaller amounts of these materials to obtain a given percentage.

MAGNETIC NON-IRON ALLOYS.

Prof. J. H. Flemings and R. A. Hadfield in a recent Royal Society paper, give the latest results of their work of investigation of the magnetic qualities of some alloys not containing iron. The alloy experimented with was composed of manganese, 22.42 per cent.; copper, 60.49 per cent.; aluminum, 11.65 per cent.; carbon, 1.5 per cent.; silicon, 0.37 per cent.; iron, 0.21 per cent. About 2 or 3 per cent. of slag was intermingled, mostly consisting of manganese and silicon oxides, with slight traces of metals other than the above mentioned. The conclusions of the paper are as follows:

The above alloy exhibits magnetic properties which are identical with those of a feebly ferro-magnetic material.

The magnetization curve is of the same general form as that of a ferro-magnetic metal, such as cast-iron, and indicates that with a sufficient force a state of magnetic saturation would most probably be attained.

The alloy exhibits the phenomenon of magnetic hysteresis. It requires work to reverse the magnetization of the material and to carry it through a magnetic cycle.

The material has a maximum permeability of 28 to 30, which is not greatly inferior to that of the values reached for cobalt or a low grade of cast-iron for small magnetic forces, and occupies a position intermediate between the permeability of the ferro-magnetic and the merely paramagnetic bodies, such as liquid oxygen and ferric chloride.

The material exhibits, therefore, the phenomenon of magnetic retentivity and coercivity. It is not merely magnetic, but can be permanently magnetized.

A further conclusion is that the magnetic properties of this alloy must be based on a certain similarity of molecular structure with the familiar ferro-magnetic metals. The hypothesis which best fits the facts of ferro-magnetism is that materials such as iron, nickel and cobalt, are composed of molecular groups, which are permanently magnetic, and that the process of producing or changing the evident magnetization of a mass of these metals consists in arranging or disturbing the positions of these molecular magnets. Since, then, we have in this alloy an instance of fairly strong ferro-magnetism produced by an admixture of metals possessing in themselves separately no such property, it follows that ferro-magnetism *per se* is not a property of the chemical atom, but of certain molecular groupings. The importance of this fact cannot be easily overstated. It shows us that in spite of the fact that ferro-magnetism has been hitherto regarded as the peculiar characteristic of certain chemical elements—iron, nickel and cobalt —it may, in fact, depend essentially on molecular grouping composed of a comparatively large number of molecules,, and, hence, it may be possible to construct alloys which are as magnetic, or even more magnetic, than iron itself.

Commenting on the paper, our London contemporary, the *Electrician*, says that the discovery of the secret of the molecular grouping referred to would be of immense importance, as it will lay bare the whole mystery of magnetism, and might make possible the manufacture of a material even more magnetic than iron itself.—*Electrical World.*

Mechanical and Engineering Section.

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Superheated Steam in Locomotive Service.

By W. F. M. Goss,

Director of the Engineering Laboratory, Purdue University.

[The author, in this paper, discusses in an instructive manner, the development and present state of this latest phase of locomotive engineering, giving illustrations of the most promising inventions that have been introduced.—The Editor.

1. *The American Locomotive* has in recent years undergone many changes. Its weight has increased enormously. Extensions of grate to give increased coal-burning capacity have led to changes in the arrangement of wheels. Boilers have been made larger and the pressure carried by them has been raised. Numerous and widely varying experiments have been made in the application of the compound principle, accompanied by an extensive adoption of a single type. Conceptions which at one time were thought to be fundamental have been upset. Whereas designers used to judge the desirability of every detail entering into the construction of a locomotive by its degree of simplicity, the mechanism of the modern locomotive has in the last decade become more and more complicated and the machine as a whole has been made to bristle with fixtures and attachments, no one of which is simple.

These changes have come in response to a demand for higher efficiency or greater power, and the demand in its fullness is not yet satisfied, if indeed it ever can be. In his efforts to keep pace with a growing demand, and at the same time to observe limitations affecting weight, wheel-base and over-all dimensions, which must control in the upbuilding of his proposed machine, the designer neglects no principle which is likely to aid him. Just at present, many different interests are endeavoring to apply in locomotive service the principle

of superheating, the application of which necessitates the use of a considerable amount of apparatus hitherto unknown in locomotive service, and introduces problems which until recently have been regarded as difficult of solution. Nevertheless, so much has already been accomplished and the results are withal of such promise, that the superheating locomotive, while on the lowest round in the ladder of professional favor, has a fine footing and is likely to climb higher. Recognizing this fact, it is my purpose to inquire briefly concerning the principles underlying its action and to reach some conclusion as to the probability of its ultimate success.

2. *Superheated Steam.*—In the process of its generation, steam always has the temperature of the water from which it is produced. What this temperature is, depends entirely upon the pressure to which the water and the steam above it are subjected. Whenever the steam is in the immediate presence of the water from which it is generated, it is said to be saturated. If it becomes mixed with water, it is moist steam. Moisture in steam does not affect its temperature, which is always dependent upon its pressure, the temperature rising or falling as the pressure is increased or diminished. But if steam is removed from the immediate vicinity of the water, from which it was generated, it may be heated to a higher temperature than that of the water from which it is generated, even though its pressure is not increased. It then becomes superheated steam, the extent of the superheating being measured by the difference between its temperature and that of saturated steam of the same pressure.

Superheated steam can never carry moisture. If heat is gradually taken from it, the degree of its superheat is reduced, and finally the superheating disappears. It is then dry and saturated; with any further withdrawal of heat, condensation begins and the mixture becomes part steam and part water. One important difference, then, between superheated steam and saturated steam is to be found in the fact that the former may be made to give up heat without undergoing condensation, whereas any yielding of heat by saturated steam results in condensation. Because of this difference, the behavior of superheated steam in an engine cylinder is quite different from that of saturated steam, with the result that the substitution of

superheated steam for saturated steam is attended by an increased efficiency of an engine. The actual differences in action are complex, but a discussion of them in general terms will not be difficult to follow.

3. *Heat Interchange.*—The average temperature of the metal of an engine cylinder is much lower than the steam in the boiler from which it derives its heat. The reason for this is to be found in the fact that while for one instant it is exposed to the influence of boiler temperature, the next it is exposed to the influence of exhaust temperature. Its exposure is not unlike that of a bar of iron which is alternately thrust into the fire and withdrawn therefrom. Just as a bar thus exposed can never reach the temperature of the fire, so the temperature of the cylinder of a moving engine can never equal that of the steam at initial pressure.

Following now with some care the action which occurs in an engine cylinder, it will be found that there is a constant interchange of heat between the steam and the metal of the cylinder which surrounds it. Dealing first with an engine using saturated steam, and assuming that the piston is at the beginning of its stroke, it is evident that as the saturated steam rushes through the open port, it finds the metal of the cylinder at a comparatively low temperature. The incoming steam must, therefore, give up a portion of its heat to raise the temperature of the surrounding metal. For each unit of heat thus transmitted to the metal, a portion of the saturated steam must be condensed. This condensation continues with the forward movement of the piston until by the time the cut-off is reached, a considerable portion of all the steam admitted exists in the cylinder only as water. While the amount of steam which is thus lost is affected by many things, it may be said in general that under ordinary running conditions, from a quarter to a third of all steam admitted is condensed during admission. The moisture thus formed covers the interior walls of the cylinder just as atmospheric moisture, on a warm day, covers the exterior walls of an ice pitcher. Proceeding with the analysis it will be found that as the piston goes on its course, and expansion begins, the pressure and temperature of the steam gradually fall until a point is finally reached where the steam within the cylinder is no longer hotter than the surrounding

walls. At this point, condensation ceases. Still later, the temperature of the steam falls below that of the walls and the transfer of heat is reversed. The metal of the cylinder now being hotter than the steam and water in the cylinder, a portion of the moisture upon its walls is re-evaporated. This restoration involves but a small per cent. of the initial condensation and it occurs too late in the stroke to be of material service. When the exhaust-port opens, therefore, a very large portion of the initial condensate is still present in the cylinder as water. The metal of the cylinder being now much hotter than the moisture which clings to it, gives up heat rapidly, converting the water into steam which, when generated, passes out of the exhaust-port of the engine. It is important to observe that the heat which is required to evaporate this moisture, resulting from the initial condensation, all comes from the walls of the cylinder. In consequence of this action, the walls are cooled far below their mean temperature, making it necessary for the incoming steam of the next stroke to again heat them, and the whole process must be repeated with each successive stroke of the engine. It will be seen also that by the process described, heat is taken from the steam during admission before it has time to do any considerable work upon the piston. It is restored in part, late in the stroke, but chiefly at a time when the open exhaust valve furnishes a way of immediate escape. It enters the cylinder as steam and leaves it as steam, but during the interval between admission and exhaust, which events mark the effective stroke of the piston, a considerable portion of the whole exists as water. The action of the walls in thus depriving the steam of much of the power it would otherwise have, may be likened unto that of a thermal sponge, which absorbs heat during the effective strokes and gives it out again when its chances for doing work have passed. For the purpose of the present discussion it is important to observe that in this action, the walls are greatly aided by the presence of that moisture which is the vehicle upon which the heat is conveyed away. The problem of producing a highly efficient engine is, in fact, one of reducing the interchange of heat between the steam and the metal of the cylinder, or of adopting a cycle which will serve completely or in part to neutralize its effect.

4. *Methods by which the Interchange may be Reduced.*—A re-

duction in the interchange of heat between the steam and the walls of the cylinder of reciprocating engines may be effected by the adoption of one or more of four different procedures, which may be described as follows:

The first to be mentioned is that which involves a cylinder of non-conducting material. It has been shown that the interchange loss in existing engines is due chiefly to the ease with which the cast-iron of their cylinders receives and gives up heat. If it were possible to find and make practical use of a metal having a lower degree of conductivity, the interchange would be less. But while a great deal of ingenuous work has been done along this line, the construction problems are difficult, and the development of an engine having cylinders of low conductivity, suitable for every-day work, has yet to be accomplished.

A second plan is that of steam-jacketing, in the working out of which, steam is circulated in a space or "jacket" surrounding the working cylinder.The pressure of the jacket steam is equal to or greater than that admitted to the cylinder, and hence the jacket temperature is higher than the average temperature within the cylinder. Its effect, therefore, is to prevent, in some measure, the cooling of the cylinder during exhaust. While its use does not result in the maintenance of a constant temperature in the cylinder walls, it materially reduces the range of change which would otherwise take place. Hence, the exhaust losses are diminished and the initial condensation materially reduced. Steam jackets are much used on stationary and marine engines of the better sort, but have not yet been extensively used in locomotive service.

Another plan for reducing interchange of heat is to be found in the adoption of compound or triple expansion cylinders. By this plan, the desired result is sought by dividing the total range of temperature to which the engine is subjected into two or more stages, and by then assigning a cylinder to each stage. By these means, the difference between the initial and final temperature to which any given cylinder is subjected is reduced. In a compound engine, it is but half that of a single expansion engine, and in a triple expansion engine, but one-third that of a single expansion engine, the initial and final temperature being the same in all cases. As all heat transfer is

proportional to the difference in the temperature of the source of heat and the object heated, such a reduction in the range of temperature to which the walls are exposed results in a material reduction in the initial condensation. With respect to compounding, locomotive builders have made heroic endeavors to keep up with the general progress of steam engine design, with results the full significance of which cannot now be estimated.

A fourth plan for reducing the interchange is that of superheating the steam before admitting it to the engine cylinder. As already pointed out, superheated steam may be made to give up heat without producing condensation. When such steam is admitted to an engine cylinder, the walls which have been left cool by the preceding exhaust are raised in temperature by the heat of its superheat. If the degree of superheating is sufficient, there will be no initial condensation, consequently, as the stroke proceeds, there will be no accumulation of moisture on the walls of the cylinder, and when exhaust occurs, there is no moisture to be vaporized. In the absence of moisture which can act as a vehicle in conveying heat through the exhaust port, the walls are but little cooled during exhaust, and hence require but little initial heating. The accomplishment of the initial heating without the production of moisture reduces the interchange throughout all portions of the cycle. The effect produced by superheating is in fact cumulative.

Summarizing briefly, it may be said that superheated steam, in common with jacketing and compounding, improves the performance of the engine by reducing the interchange of heat between the steam in the cylinder and the metal surrounding it. The precise manner in which this is accomplished is, however, different for each of the three cases. Thus, with superheated steam, the interchange is reduced by the complete or partial elimination of moisture in the cylinder; with jackets the interchange is reduced by a suppression of evaporation during exhaust; and with compound cylinders, it is reduced through a reduction in the range of temperature to which the cylinder walls are exposed. When, therefore, it is announced that a locomotive using superheated steam has given a performance equal to that of a compound locomotive, there is no occasion

for surprise, for the possibility of such a result may easily be demonstrated.

5. *Practical Difficulties in the Use of Superheated Steam.*—As long ago as the early sixties, superheaters were in use upon certain steamers operating on the Atlantic coast. The value of such arrangements were not at all questioned by those concerned with their operation, and elaborate tests by Isherwood served to confirm the popular impression. But the superheaters were difficult to maintain, even though the steam pressure was no more than forty pounds, and notwithstanding the advantage derived from their use, the trouble arising from them led to their gradual abandonment upon the steamers referred to.

In 1877, a series of elaborate tests were conducted by Mr. George B. Dixwell upon a small Harris-Corliss engine when supplied with saturated and superheated steam. These, while confirming previous conclusions as to the advantage of superheated steam, did not at once serve to enlarge American practice in connection therewith. In recent years, while superheaters have occasionally been used in various classes of service, they have gained no footing in our practice, and gradually American engineers have come to believe that the cost of their maintenance quite offsets the advantage to be derived from their use. If, it is argued, the maintenance of the superheater gave trouble when steam pressure was only forty pounds, and the temperature of the superheated steam no more than about 400 degrees F., how much more difficult is the problem to-day when the temperature of saturated steam approaches 400 degrees and that of superheated steam to be effective must be not less than 600 degrees F.? This view is well represented by Professor Peabody in his text-book on "Thermodynamics," which is as follows:

> "Whenever superheated steam has been used so as to give a notable gain in economy, the superheating has been accomplished in a separate apparatus, which has taken the form of a coil of pipe exposed to the products of combustion beyond the boiler. Now, it is the accepted experience of boiler-makers that surfaces exposed to the fire must be of moderate thickness or they will rapidly waste away. Thus, it is not desirable to make furnace-flues more than half an inch thick, and if they are made thicker they are liable to waste away until they are reduced to

about that thickness. Plates and tubes if thin enough endure long service in a boiler when exposed to the fire because they are kept at a moderate temperature by the water in the boiler. If steam is to be superheated strongly in a coil of pipe or other device which is exposed to hot gases, the metal of the superheater must be strongly heated and is sure to waste away rapidly. There is no material that can stand long service when exposed at once to a high pressure and a high temperature. There is little risk, therefore, in predicting that all superheating devices now used will eventually be discarded for this reason."

While it is true that occasionally during the past twenty years, superheating has been resorted to in connection with stationary plants of unusual significance, enough has been said to show that American engineers threshed out the problem of superheating many years ago, and have since been content to let the matter rest undisturbed. Very recently, however, it has again occupied their attention, and just now it is a subject of more than ordinary interest to locomotive designers. It is but fair to add that this interest has been greatly stimulated by reports from abroad.

6. *Recent Development in the Use of Superheated Steam.*—Abroad, and especially in Germany, for more than a decade there has been a great awakening of interest in superheated steam. The technical schools of Germany have for ten years past been experimenting with large superheaters in connection with their experimental engine plants, and in their practice, as well as in their more scientific work, the Germans have been and are devoting themselves to the problem of superheating. Among those who have had a conspicuous part in this movement, perhaps none have been more energetic or successful than Herr Wilhelm Schmidt. Some ten years ago, Herr Schmidt began the introduction of stationary boilers and engines designed for the generation and use of superheated steam. The Schmidt system as applied to stationary plants involves special construction both in boiler and engine, by means of which a consumption of less than 1.7 pounds of coal per horse power hour has been obtained, while in the case of one plant, the results of which have come under the writer's observation, the consumption was reduced to 1.02 pounds per hour. This is a record of high performance.

The Schmidt stationary boiler has a vertical shell within

which is arranged a large corrugated fire-box and combustion chamber, extending approximately two-thirds the height of the shell. The grate has a smaller area than the cross-section of the fire-box, the difference being effected by a few courses of fire-brick which make up a cylindrical lining for a short distance above the grate. Higher up, the combustion chamber is crossed by circulating tubes of considerable diameter, the surface of which, together with that of the corrugated tube making up the fire-box and combustion chamber, constitutes the direct heating surface. From the top of the combustion chamber, a single flue of considerable diameter opens out through the upper head of the boiler. This flue receives the products of combustion from the fire-box and delivers them to a superheater arranged above the boiler. The superheater consists of pipe 2.4 inches in diameter arranged in a series of flat coils, one above the other, there being as many as twelve coils, while above these superheating coils are other coils forming a feed-water heater.

The action of such a device is apparent. The comparatively small amount of heating surface and the short and direct passage between the furnace and superheater serve to supply the latter with gases at a high temperature, while the extent of superheating surface and the presence of the feed-water heater beyond serve to reduce their temperature to satisfactory limits before they are allowed to escape into the chimney.

Encouraged doubtless by his success in stationary practice, Herr Schmidt has extended the application of his system to locomotives, with the result that from four or five superheating locomotives of a more or less experimental character which were placed in service on the Prussian State Railway, the number has now been increased to more than fifty. It is claimed that the performance of these locomotives is twenty-five per cent. better than that of similar locomotives using saturated steam.

Inspired by German success, American builders and railroad companies have entered upon a period of cautious experimentation. A Canadian railroad, which has been operating one or two superheating locomotives for several years, has recently given orders for a considerable number of such machines. Several of the larger roads of this country are operating one or

more superheating locomotives and the indication is that many more will be forthcoming. For the most part, practice in this country has followed closely the lines of the Schmidt design, though recently certain modifications of this design have appeared.

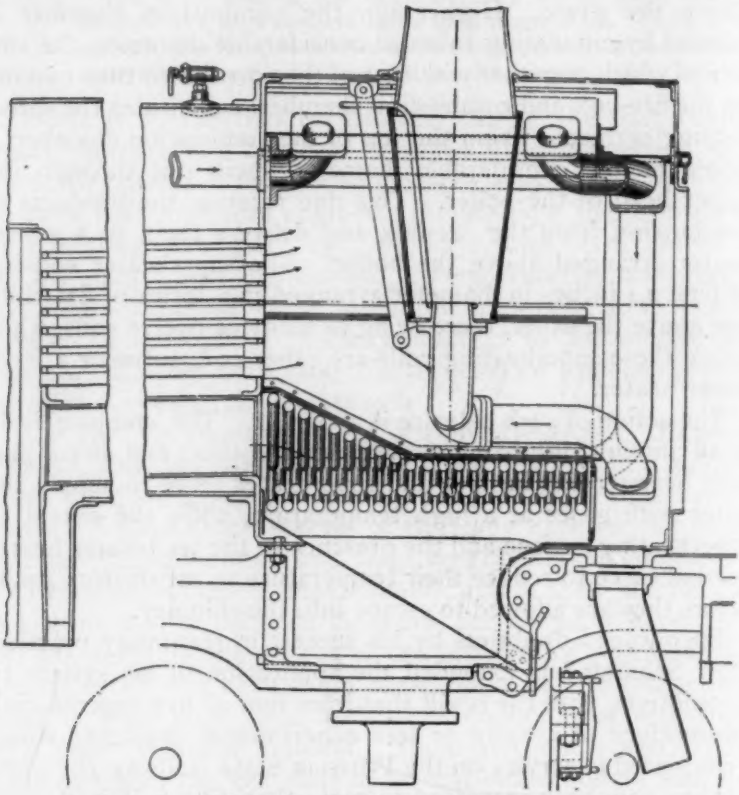

Fig. 1. Longitudinal-section of smokebox with Schmidt superheater.

*7 Locomotive Superheaters.**—The different forms of superheaters which have thus far been placed in service involve no material change in the exterior outline of the locomotive. Their application in all cases leads to some loss in the extent of

*The writer acknowledges the assistance of Mr. Fritz B. Ernst, Instructor in Car and Locomotive Design, Purdue University, in preparing illustrations and arranging descriptions under this heading.

direct heating surface. Four forms which thus far have attracted public attention may be described as follows:

The Schmidt superheater is shown in longitudinal section by Fig. 1. Its construction involves a flue ten or twelve inches in diameter, extending from the fire-box to the smoke-box

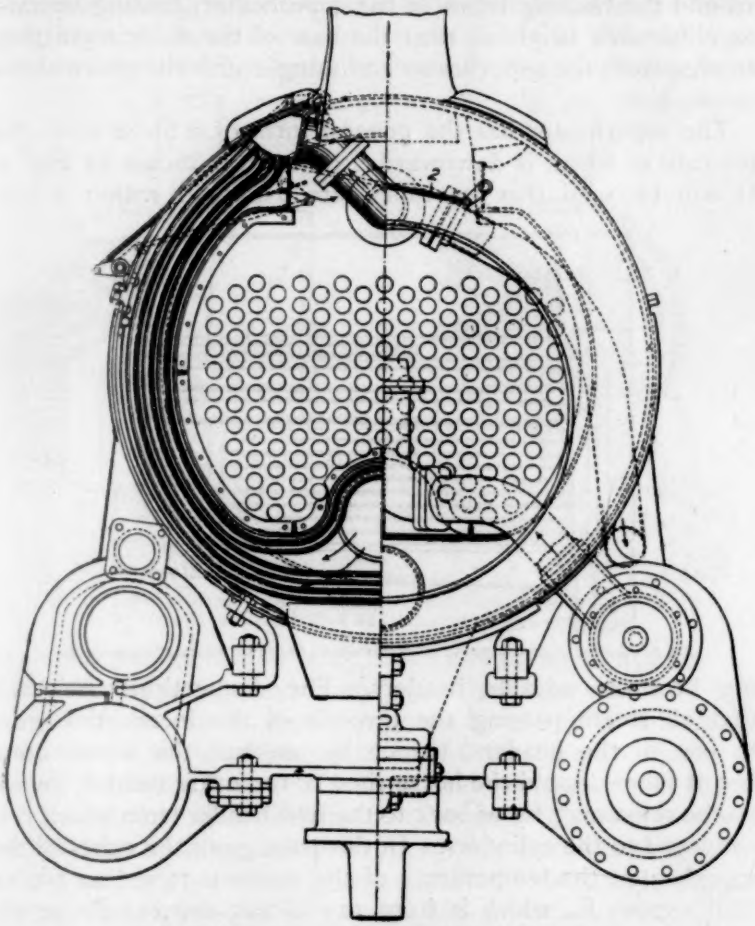

Fig. 2. Cross-section of smokebox with Schmidt superheater.

along the lower portion of the barrel of the boiler. This flue displaces from twenty to thirty of the usual tubes. Its purpose is to deliver to the superheater located in the smoke-box a considerable volume of furnace gases. The large size of the

tube permits the delivery of the gases at a high temperature. The construction is such that while the gases from the smaller tubes of the boiler are free to pass directly up the stack as in the ordinary locomotive, those from the large tube pass into the casing of the superheater within which they circulate around the heating tubes of the superheater, passing upward on either side to points near the base of the stack when they emerge from the superheater and mingle with the gases of the smoke-box.

The superheater has the general form of a horse-shoe, the toe-calk of which is downward. Its form is shown by Fig. 2. It will be seen that its tubes are arranged within a cas-

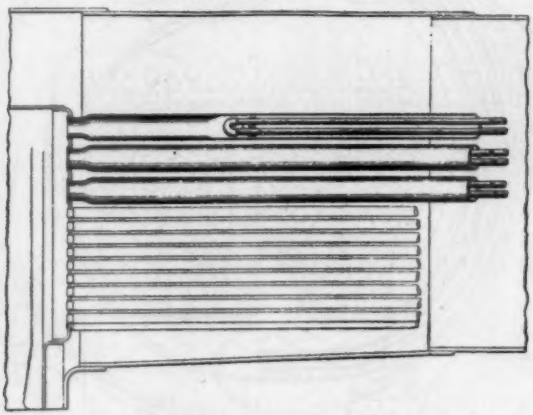

Fig 3. Section of shell showing tubes containing improved Schmidt superheater.

ing between suitable headers. The connections are such that all steam passing the throttle of the locomotive goes to one of the headers, thence by one-half the whole number of tubes around the horse-shoe to the other header, thence by the remaining tubes back to the first header from which it is conveyed to the cylinders. In this passage of the tubes of the superheater, the temperature of the steam is raised to 500 or 600 degrees F., which is from 125 to 225 degrees above the temperature of saturated steam at usual boiler pressure.

The Schmidt improved superheater is shown in part by Fig. 3. In this construction, the nesting of the superheater tubes in the front-end is abandoned for a system of small return tubes arranged within certain of the fire-tubes which are somewhat

enlarged to accommodate them. As is well shown by Fig. 3, the ends of the fire tubes are contracted where they join the fire-box sheet, and the tubes of the superheater are threaded into return fittings. In this construction, the temperature to which the heating tubes are exposed is determined by the nearness they are allowed to approach the fire-box. The connections at the smoke-box end are shown by Fig. 4. Steam from

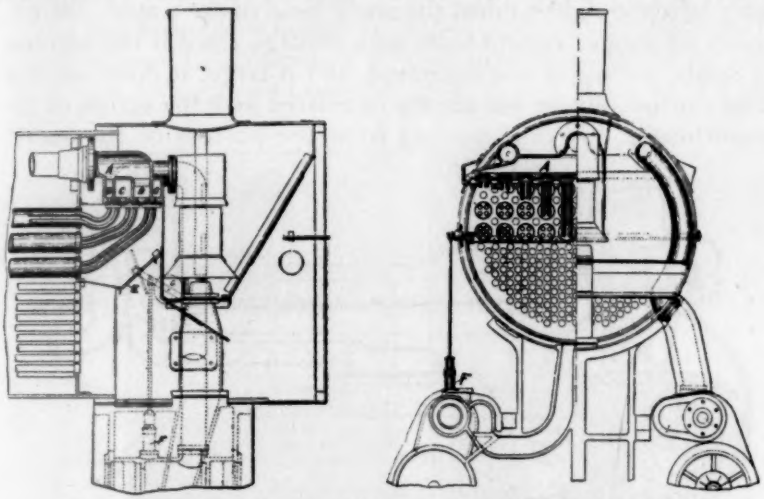

Fig. 4. Longitudinal-section of smokebox with improved Schmidt superheater.
Fig. 5. Cross-section of smokebox with improved Schmidt superheater.

the boiler passes into a large double-chambered header, A, which extends across the smoke-box. From the chambers BB in this box, the steam passes down into one end of the small pipes, thence back to the return bends near the fire-box and back to the compartments C C of the header from which point it is conveyed to the cylinders. A damper, E, serves to control the flow of furnace gases through the superheater. It is so pivoted and weighted that it remains closed except when steam is being used in the engine cylinder, thus protecting the superheater from the action of the fire when no steam is being used. Whenever steam is admitted into the valve box, however, it also enters cylinder F, (Fig. 4), which opens the damper. Fig. 5 shows cross sections of the front-end and makes clear the manner of nesting the superheater tubes in groups of four.

The Pielock superheater (Fig. 6) consists of a box built en-

tirely within the barrel of the boiler and enclosing a certain length of the usual tubes in such a way as to make the enclosed portions of the tubes available as superheating surface. The tubes are lightly rolled into the end plates of the superheater box to exclude the water. It is stated that no trouble is experienced in preventing leakage as the pressure within the box and in the boiler is essentially the same, and the joints need only be made tight against the static head of the water. Moreover, no danger results from such leakage since if the amount is small, the water is evaporated, and if large, it does not disable the locomotive but merely interferes with the action of the superheater. A tube passing from the bottom of the super-

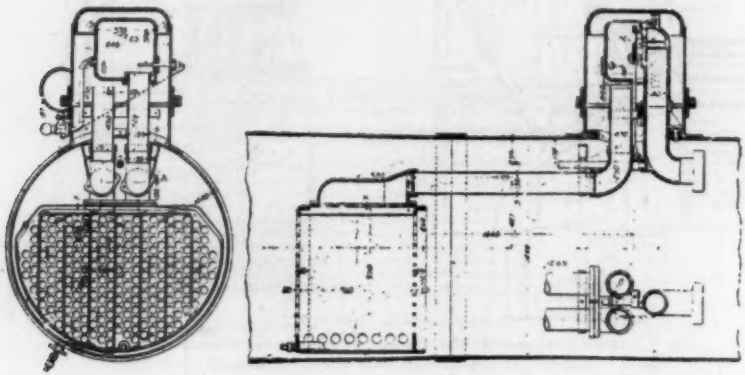

Fig. 6. The Schenectady locomotive superheater.

heater out through the shell of the boiler is fitted with a drain cock, which may be used to ascertain if the superheater is tight. No special fastening of the superheater box is necessary as the box nearly floats and the surplus weight is taken by the large number of tubes to which the box is fastened.

Steam is taken from the dome of the boiler, is conveyed to the heater box where it circulates among the tubes, after which it passes to an enclosed chamber in the dome, thence past the throttle valve to the cylinders. To promote the circulation of steam within the superheater, the box is divided by vertical partitions in several compartments which are joined by openings placed alternately at the top and bottom. These are well shown in the section view of Fig. 6. Two views of a Pielock superheater from photographs are shown by Fig. 7. It is evi-

dent that the degree of superheating may easily be regulated by varying the length of the superheater or its position relative to the fire-box.

It will be of interest to note that the von Borries compound locomotive, exhibited at the Louisiana Purchase Exposition by the Hanover Locomotive Works, and tested by the Pennsylvania Railroad Company, was fitted with a Pielock superheater.

The last form to be described is that of the Cole superheater, which is now being applied in considerable numbers by the American Locomotive Company (Fig. 8). It is, so far as I am

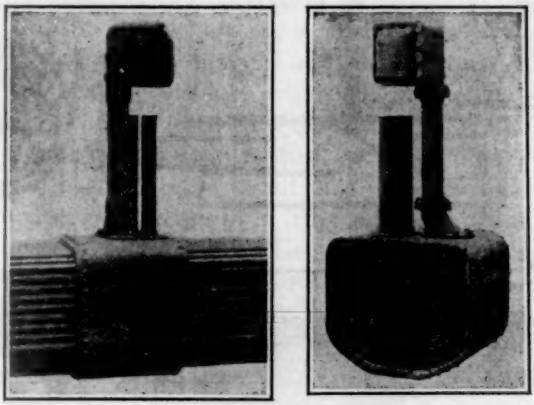

Fig. 7. The Pielock superheater.

informed, the only locomotive superheater which is being projected in this country. It at once suggests the improved Schmidt construction but in its details it is quite different. The fire-tubes in which the heater tubes are placed are of uniform diameter throughout their length, and are but one inch longer than the normal tube. The heater tubes are not looped, but are in single lengths only. There are consequently no joints in the heater pipes. The back end of each heater-tube is closed by welding, the scarfed end being drawn to a form designed to support the heater-tube. The end of the heater-tube is not in the center of the fire-tube but is raised to the top of the latter, thus increasing the area of the clear space below and lessening the chance of

the tubes becoming stopped by lumps of fuel. The smoke-box end of the heater-tube is straight. Connections for the circulation of steam are as follows:

Steam from the throttle is delivered into the upper compartment of a T-shaped head, which extends nearly across the width of the smoke-box. The lower compartment of this fitting is in pipe connection with the cylinders. To the front side of the T-shaped head are attached a number of cast headers, the joint being made with a copper gasket as in steam-chest practice. Each header is sub-divided by a vertical partition into a forward and back compartment. Through holes in the front wall and the partition wall of the headers, the tubes of the superheater, $1\frac{3}{4}$ inches in diameter, are inserted and pushed

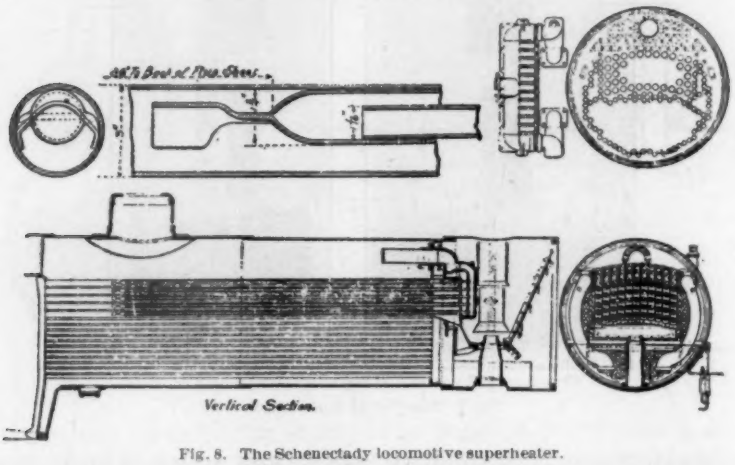

Fig. 8. The Schenectady locomotive superheater.

back into the fire-tube, the forward end being expanded into the back wall of the header. Next, the circulating tubes, $1\frac{1}{16}$ inches in diameter, the forward ends of which are expanded into special plugs, are inserted within the heater-tubes and the plugs screwed to place in the vertical partition wall of the header. The openings in the forward wall of the headers are then closed by plugs. In action, steam passing the throttle, finds its way to the forward compartment of the headers, thence through the circulating tubes to the back end of the superheater tubes, thence through the superheater tubes to the back compartment of the headers, and thence by branch pipes

on to the cylinders. A damper arrangement similar to that employed in the Schmidt superheater is used to protect the heater-tubes from excessive heat when steam is not being passed through them.

8. *Concerning the Probable Success of Superheating in Locomotive Service.*—The prediction of Professor Peabody, already quoted, to the effect that all superheating devices will in the end be discarded, has doubtless been generally accepted by the rank and file of American engineers. For them the problem has had no mysteries. They have understood the thermodynamics of the problem. They have admitted that the use of superheated steam in engines is always attended by a more efficient cylinder action, but past experience has taught them that the difficulties in maintaining a superheater were too great to justify its continued use. They have argued that since this was true thirty years ago when steam pressures were so low that the temperature of the superheated steam was less than that of saturated steam of to-day, the problem of superheating is now vastly more difficult than it has ever been before. The prevalence of this view in this country naturally leads many to question whether even Germany's great progress and the more recent but equally promising start of the American Locomotive Company are as yet sufficient to insure a future for the practice. In raising this question it is not intended to minimize the value of the elaborate researches of Schmidt, Schroter and other German investigators, or of the equally valuable experience which has been gained in the application of principles. The endeavor has been made to make the fact clear that between apparently most promising and even masterful experimentation and an assured success in practice, a broad gulf is fixed, and that the voyage across is not yet finished.

Turning now from convictions based on previous experience, and approaching the subject without prejudice, it is well, first of all, to recognize the fact that when a principle in operation is correct and when it is generally understood, it is never safe to assume that the means whereby it may be utilized will forever fail to be forthcoming. The reverse is likely to be true. The efforts to use superheated steam in the cylinder of an engine are based upon correct thermodynamic principles, and hence, sooner or later, practice will embrace it. Again, it goes with-

out saying, that with the better materials and larger experience of to-day, the problem of producing and utilizing superheated steam can be approached with greater certainty than was possible in the practice of many years ago. Proof of this is to be seen in the degree of success already achieved.

Examining the question broadly, we shall find that locomotive service is more favorable to the use of the superheater than any other in which it has been tried. The installations with which we have hitherto dealt have served in stationary or marine practice. The superheater of these plants has either been a separate boiler-like device, in which no water was carried, or has been so combined with the boiler as to always be in close communication with its furnace. Under these conditions, when the engine throttle is closed, the circulation of steam within the superheater tubes ceases and the metal of the tubes, together with the entrapped steam within them, remain exposed to the undiminished intensity of the furnace action. In this manner, the tubes are often heated to very high temperatures, a result which when frequently repeated leads necessarily to a failure of the superheater. Again, when after an interval of inactivity, the engine is started, the steam which has been held back within the superheater until it has been raised to an enormously high temperature, passes on to the engine, often times retaining enough of its heat to burn the lubrication and sometimes to destroy the rod packings. But all difficulties of this class which to a greater or lesser degree have appeared in the operation of every stationary engine plant using superheated steam, are doubtless avoided in the locomotive, for in this machine, the rate of combustion varies with the volume of steam used. When the throttle is open, the fire burns brightly; when it is closed, its activity is at once suppressed. When there is no steam passing within the tubes of the superheater, the gases circulating around the tubes are comparatively low in temperature, and when the conditions are so changed that the temperature of the gases becomes maximum, the volume of steam passing the tubes is greatest. Just as the draft of a locomotive responds to the varying demands which are made upon the boiler, so the volume of heat which is available for superheating varies with the quantity of steam which is to be superheated. The details of several of the designs described provide

that when the blower is on, dampers are closed, which prevent the circulation of gases in the superheater, so that it is only when the throttle is open that the superheater does work. While it is my opinion that the automatic damper is in fact unnecessary, it is certainly true that with it, overheating of the superheater becomes impossible. In view of the highly favorable character of all these conditions, it is likely that it will be found easier to maintain a superheater on a locomotive than in connection with any other type of engine, and, moreover, that superheating in locomotive service may be a pronounced success, while in other classes of service, its future may still be problematical.

9. *Efficiency and Power.*—It may be accepted as beyond question that the use of superheated steam will materially improve the efficiency of the locomotive. The saving resulting from its use is a two-fold one. For the development of a given power, the cylinders of the superheating locomotive require less steam, and as the demand for steam diminishes, the efficiency of the boiler increases, so that there is not only a saving in steam but a proportionately greater saving in coal. The German claim that 25 per cent. of the coal burned is saved by the use of superheated steam is as a general statement probably extravagant, but it is not so high as to be impossible.

Again, while economy in the use of fuel is of great importance, it is in many classes of service secondary to questions affecting the output of power. Modern conditions impose many restrictions and limitations as to the weight and dimensions of a locomotive, while at the same time they call for the development of greater power. It is, therefore, important to note that in locomotive service anything which improves the efficiency of the machine, may be utilized to extend its limit of power. The power delivered per unit weight of coal burned and also the power delivered per unit weight of locomotive, is increased by the use of superheated steam. It appears, therefore, that one way in which the power of locomotives may be increased is to equip them for superheated steam.

Obviously, it should not be claimed that full advantage is to be had of the increase of economy and of power at the same instant. One effect is always sacrificed for the other. Under ordinary conditions of running, full advantage is derived from

the improved economy while in an emergency when the locomotive must be worked at its maximum power, then at a temporary sacrifice of efficiency, limit of power may be raised.

10. *Incidental Considerations.*—A fact of interest which should appear in the use of superheated steam is a decided improvement in steam distribution which indeed may constitute a factor in the resulting economy. With superheated steam, the initial condensation is suppressed and the ports are required to pass only that steam which is effective in doing work, whereas with saturated steam they must pass in addition to this, that which is represented by the initial condensation. Assuming port areas to be the same, those for a superheating locomotive are in effect from 20 to 25 per cent. more liberal than for a locomotive using saturated steam. In high speed service, this becomes a matter of consequence.

An objection frequently raised against the use of superheated steam is to the effect that it increases the difficulty in cylinder lubrication. Troubles of this kind have in fact been common enough in stationary practice, but the fact should not be lost sight of that they have followed a period when for some reason the superheater has been overheated. Under normal conditions, an engine supplied with superheated steam has saturated steam in its cylinders, and the maximum temperature of the cylinder walls is not higher than when saturated steam is used. It has already been shown that there is little danger of overheating a locomotive superheater and consequently difficulties with lubrication are not to be found.

11. *In Conclusion,* to briefly summarize preceding statements, it appears that from an academic point of view, the conditions of locomotive service are very favorable to the use of superheated steam; that its use makes possible a better distribution of steam, it greatly improves the economic performance of the locomotive and increases the capacity of the locomotive for doing work; that the maintenance of the superheater is not likely to prove serious nor is any trouble to be expected in securing satisfactory cylinder lubrication; that the adoption of superheated steam in locomotive service can probably be accomplished without greater difficulty than that which attends the introduction of any other important detail entering into loco-

motive construction; and that substantial progress has already been made in the application of the principles involved.

ENGINEERING LABORATORY, PURDUE UNIVERSITY,
MARCH 1, 1905. LAFAYETTE, IND.

DISCUSSION.

MR. M. N. FORNEY.—The subject of superheating of steam is one that has been discussed for a long time. In Rankine's book on the Steam Engine, written nearly fifty years ago, there is a demonstration showing the economies which may be attained by superheating, and since then it has often been tried, and such trials have shown that a very important saving in fuel can be effected thereby. When Rankine wrote his book only animal oils were used for lubrication, and vegetable fiber for piston and valve-rod packing. Neither of them would stand a high temperature, and consequently when that of the steam used was materially increased, the oil and hemp packing were destroyed by the increased heat. As a consequence the cylinders, packing and piston-rods were abraded and injured. Away back in the fifties, when Mr. Henry Tyson was master of machinery on the Baltimore & Ohio Railroad, he had some of the upper row of tubes in a locomotive boiler bent upward, so that the curved portion projected into the steam space above the water. This had the effect of heating the steam more or less, but when it was tried, the cylinders were quickly abraded and ruined, so that the experiment was abandoned. The introduction of mineral oil, which will withstand a much higher temperature than animal oil, and of metallic piston-rod packing, makes the use of superheated steam practicable now, when formerly it was not, and during the past decade or two, we find that renewed attention has been given to the subject and some very remarkable economies are reported as the result of its use in stationary, marine and locomotive engines, and the advantage in the latter has now been distinctly recognized.

But in the adoption of any improvements in locomotives the fact must be recognized that it is often easier to save coal than it is to save money. In other words, the cost of the devices for effecting the economy and the expense of maintaining may amount to more than that of the fuel saved.

There is another consideration, which should never be lost sight of. That is that the prime purpose of locomotives is to haul cars on railroads, and that anything which interferes with this in any way, by getting out of order, which lessens the amount of service which a locomotive will perform, is quite certain to be abandoned. A locomotive on a railroad occupies a relation to it which a reaping machine does to a farm. The prominent purpose of such a machine is to cut the grain when the harvest is ripe. Now, any device, no matter how useful, which will interfere with this purpose, at the critical period of harvest, etc., is quite sure to be condemned and its use abandoned. On a railroad, the delay of trains, especially with the line is crowded with traffic, interferes very seriously with the business of the road, and this becomes costly. Therefore any so-called improvement in locomotives which will lessen the amount of work which they can do in a week or month or a year, is quite sure to fall into disuse. Superheating, like every other improvement, will be subjected to this test and if it is found after full trial that locomotives with superheaters will do more work and with less fuel than they will without, they will be generally adopted, otherwise, it is quite safe to predict they will not be. To save fuel alone is not a sufficient advantage to secure their general use. They must do this without materially increasing the other expenses or diminishing the amount of work the locomotive will do.

It is not the purpose of these remarks to throw cold water on superheating. At present the results therefrom which have been reported, look very promising, and indicate that greater economy may be attained therefrom than from any other improvements in locomotives which are now proposed, but in making out a balance sheet, it is essential to give as much attention to the debit as to the credit side.

GASOLINE MOTOR AS AN AUXILIARY TO SAILS.

An interesting application of gasoline motor for marine purposes was recently demonstrated upon the arrival in the Thames of the auxiliary vessel "Sirra," of 500 tons, from Dordrecht. This vessel is a three-masted schooner, and with the large area of sails provided in a fast boat on the high seas. The craft, however, is also intended for service upon canals, for which purpose the masts are hinged, thereby enabling them to be low-

ered for passage beneath bridges. When the sails are unavailable the boat is propelled by a gasoline motor. There is a small single propeller placed well below the water line. The motor is placed right aft so as to reduce the length of shafting as much as possible, and is controlled from the poop by means of a hand wheel and lever. The provision of this auxiliary power was strongly emphasized upon the arrival of the vessel in the Thames. Instead of waiting for the tide, or requisitioning a tug, the vessel was driven up by the gasoline motor at a steady speed of six knots, and as the masts were lowered could pass beneath the bridges easily. Such a combination of wind and motor power presents many possibilities, since a vessel so equipped has great economy in power, ease in working, and adaptability to circumstances. The "Sirra" was visited by many marine engineers interested in the problem of river navigation during her stay in the Thames. It afforded a concrete example of how the question of dealing with canal traffic may be efficiently and economically handled. Such a system is much cheaper than electrical towage both from point of initial expense and maintenance, and far more expeditious than animal traction for canals and similar waterways.—*Scientific American.*

Book Notices.

Report of the U. S. Naval Fuel Board, of tests conducted on the Hohenstein water tube boiler, showing the relative evaporative efficiency of coal and liquid fuel under forced and natural draft, as determined by an extended series of tests made by direction of the Bureau of Steam Engineering, Navy Department, Washington, D. C. Washington: Government Printing Office. 1904.

In Rear Admiral Melville's Report of 1902 allusion is made to the great importance of a correct solution of the naval boiler problem, and he points out the necessity of providing a type of water-tube boilers for the navy, of American design, and of such simple construction that ordinary firemen can take care of them without danger of damage or failure. The Oil City Boiler Works offered to build and install a boiler of the Hohenstein type, and subject the same to any test which the Navy Department might wish to make This offer was accepted, the boiler was installed at the Washington Navy Yard, and a board, consisting of Commander John R. Edwards, Lieut. Commander W. M. Parks and Lieut. Commander F. H. Bailey, was appointed to make the tests.

The boiler was enclosed in a steel house, fitted with air-lock entrance, to adapt it for forced draft, and containing a blower, air compressor, several pumps, scales, gauges, feed tanks, etc., and a set of seventeen tests were made of respectively three, four, six and eight hours' duration, alternately with natural and forced draft; burning coal. The results are grouped in several tables, and finally combined in a very interesting summary, from which we will only quote the following results:

EQUIVALENT EVAPORATION FROM AND AT 212 DEGREES PER POUND OF DRY COAL.

Forced draft	8.28 lbs.
Natural draft	10.28 "

COAL PER SQUARE FEET OF GRATE PER HOUR.

Forced draft.....47.8 lbs.
Natural draft .....21.3 "

After the completion of the coal tests, the boiler and appliances were arranged for oil tests, proper burners were put in the furnace, air compressors and oil tanks provided, and the oil fuel was injected by steam, compressed air, or both combined. All the appliances are fully described and illustrated in detail, also a number of burners of different types. Seventy-nine different tests were then made under varying conditions as to draft, burners, mode of injection, etc., and the results are compiled in tables, and finally combined in a summary, from which we quote as follows:

EQUIVALENT EVAPORATION FROM AND AT 212 DEGREES PER POUND OF OIL.

Forced draft .....10.19 lbs.
Natural draft .....14.43 "

OIL PER SQUARE FEET OF GRATE.

Forced draft .....45.97 lbs.
Natural draft .....15.25 "

As a supplement to these tests the installation of oil fuel burners and results of same of the following vessels are described and illustrated: Steamers "Nevadan" and "Nebraskan," of the Hawaiian-American Company, made by the New York S. B. Company, Camden, N. J.; steamers "Mariposa" and "Alameda," Oceanic S.S. Company, made by Risdon Iron Works, San Francisco.

Tests and voyages on the latter were reported to the U. S. Navy Department by Captain Stevenson, U.S.N., and Lieut. Commander Winchell, U.S.N.

Installations for locomotives and torpedo boats, tests on the Italian steamer "Tebe," installation on S.S. "City of Everett," of the Standard Oil Company, are also fully described, and the book closes with articles on relative prices of oil, storage on board vessels, and a general resumé on economical advantages, military considerations, etc., of liquid fuel application.

The U. S. Navy Department is entitled to the thanks of the public, and particularly of those interested in transportation, shipbuilding and manufacturing generally, for undertaking these costly experiments, and the Bureau of Steam Engineering, together with the very able board in charge of these tests, must be complimented on the careful, skilful and painstaking labor performed in making these tests and compiling their results. J. H.

Leçons sur L'Electricité professées à l'Institute Electrotechnique Montefiore, Par Eric Gerard. Directeur de cet Institut. Septième Edition, entiérement refondue. Deux volumes grand in-8 (25x16). Tome second, pp. viii+888. Gauthier-Villars. 1905. (Price, 12 fcs.)

Several previous editions of this very thorough treatise have been noticed from time to time in the *Journal*. The best evidence of its value is afforded by the announcement of the appearance of the seventh edition.

This volume treats of transformers, the distribution of electric energy; applications of electricity to telegraphy, telephony, lighting, to the generation and transmission of power, to traction, to metallurgy, and to the chemical industry. W.